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COMPRESSION OF COMPLETE DIETS FOR HORSES

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A COMPLETE horse diet in the form of a mixture of roughage and concentrate feeds has several obvious advantages over the usual separate allowances of hay and grain, e.g., economy of labor and convenience in feeding, especially where large numbers of animals are involved; economy of space in storage and transportation of feeds; and practicability of utilizing in the horse diet mill and factory byproducts such as oat-mill feed, malt sprouts, distillery byproducts, extracted pyrethrum residues, and fruit pulps.

These advantages have been recognized by the German army, which used a complete, compressed diet for feeding horses in active service during the late war. A sample of one such diet consisted of the following ingredients and proportions: 33 percent chopped straw; 17 percent grass hay; 35 percent whole oats and barley; 5 percent starch, dextrin and sugar; 10 percent of other finely divided and unidentified constituents, which included some meat scrap. The hay and straw were chopped into lengths varying from ½ to 2 inches. The mixture was well compressed into blocks or bales which were easily broken into layers so that the feed masses were of a suitable size, shape and condition to be eaten readily without excessive shattering. The general appearance and arrangement of the components in the mass suggested that the roughage may have been first rolled so that the stems were flattened, then sprayed with a fluid mixture of gelatinized starch, dextrins and sugar and fed into the compressor in such manner as to produce alternating layers of the roughage and concentrate components. The specific gravity of the block was about 0.73 gram per cubic centimeter or 45 pounds per cubic foot.

Even greater interest in this type of feed has been shown by the Russians. Thus in a report by Sorokin (1936) of investigations concerning the preparation of mixed feed cakes, it is stated that satisfactory briquettes can be made from mixed feeds (mixtures of roughages and concentrates) either with or without a binder, but that greater pressures and longer compression time are required in the absence of a binder. The preheating of both the feed mixture and the compressor was found to be an important factor in determining the minimum amount and duration of pressure required for adequate cohesion of the materials. Best results were reported to be obtained from the use of the following procedure or slight variations thereof:

preheating of compressor to 120° to 125° C.; preheating of feed mixture containing 12 to 14 percent moisture to 55° to 65° C.; use of pressures of 250 to 400 kilograms per square centimeter (or 3,548 to 5,786 pounds per square inch), and maintaining pressure for 30 to 45 seconds. The specific gravity of the cakes resulting from this procedure was said to be of the order of 1.00 to 1.25. It was pointed out that briquettes or cakes of this density required soaking before they could be either broken open or eaten by the animals.

The following year Dyakov *et al.* (1937) reported, for the same laboratories, results of practical feeding tests and of careful physiological and work-efficiency studies. In these tests the usual hay and oats diets were compared with a diet of compressed feed made from 50 percent chopped meadow hay, 25 percent flattened oats, 12.5 percent beet pulp, and 12.5 percent molasses. On the basis of the very favorable results obtained with the compressed feed, combined compressed diets similar to the one tested were recommended for horses in Russian transportation systems, in field camps of collective farms and in Soviet farm brigades.

Five years later the Veterinary and Supply Division of the Russian Army (Kooznetzov, 1942) reported excellent results from a seven months' feeding trial of a combined compressed feed involving 4,000 military horses. The formula for the mixture used in this trial differed somewhat from that in the studies reported in 1937. It was as follows: 40 percent hay, 30 percent oats, 10 percent maize feed, 13 percent wheat bran, 7 percent molasses, and 2.5 kilograms of salt per ton of feed. The horses receiving only the combined feed drank more water than those receiving oats and hay, but it was claimed that they maintained their weight better and had fewer intestinal ailments than the controls. They were found to have normal working capacity although they seemed to sweat somewhat more. The report presented many advantages resulting from the use of such a diet and no disadvantages.

In the United States a few efforts have been made to reduce the bulkiness of the horse diet. Some of these have led to a limited use, especially for overseas shipment, of double compressed hay or hay compressed to a density of 68 to 85 cubic feet per ton. Limited use has also been made in certain areas of a complete diet in meal form consisting of coarsely ground roughages and concentrates. This kind of feed has been used for the most part with work horses. During World War II the United States Department of Agriculture, at the Agricultural Research Center at Beltsville, Maryland, made some studies of the preparation and feeding of compressed diets of minimum bulk and weight that would be suitable for army horses. Feeding trials were made of complete diets consisting of mixtures of ground roughages and concentrate feeds compressed into pellets about $1\frac{1}{8}$ inches by 1 inch by 7/16 inch. These pelleted mixtures were fed experimentally as the

entire diet to horses and ponies at Beltsville with entirely satisfactory results under conditions both of idleness and of light work. The proportions of forage to grain used in the Russian briquettes, in the German bales and in the Beltsville pellets have been about the same, i.e., 40 to 50 percent of roughage. A very significant difference between the Beltsville pellets and the bales or briquettes lies in the fact that in the pellets roughages and grains were ground against a $\frac{1}{8}$ inch screen, whereas the bales and briquettes were made of chopped roughages and of grains that may have been flattened but were not ground. Although no disadvantages appeared under the conditions of the Beltsville feeding tests, some may arise under different conditions through the use of finely ground feeds.

The grinding of feeds may hasten certain changes in nutritive properties that normally occur with storage and aging, especially under warm and humid climatic conditions. Further, although it has not been demonstrated that the horse is like the cow in requiring some feed of coarse and more or less irritating texture for normal digestion, the possibility still remains that diets lacking coarse material, even though well tolerated under usual conditions by horses at rest or doing only light to moderate work, may still be more favorable to digestive disturbances under conditions of hard work and general fatigue than diets containing some coarse feeds.

In view of these possible objections to the use of diets consisting solely of ground mixtures in pellet form, some exploratory trials were made at Beltsville in an attempt to prepare the combined feeds as cakes or small bales that would permit the use of chopped hay and whole or crushed grain rather than of ground feeds.

Experimental

The first trials were made on a small Carver laboratory press in which the maximum pressure obtained was about 500 pounds per square inch. The feed mixture consisted of 40 percent of either alfalfa (No. 1 grade) or timothy hay (No. 1 grade) chopped into lengths of about 2 inches; 40 percent of oats, either crushed or whole, but not ground; and 10 percent of beet pulp. With the mixture containing alfalfa hay as the roughage, good cakes were obtained under the following condition: preheating the feed mixture to 45° or 50° C.; heating the compressor to about 120° C.; addition of 5 percent, by weight of steam to make a total moisture content of approximately 14 percent; addition of 5 percent of corn dextrin as a binder; and compression for 2 minutes. The resulting cakes were 1 to 2 inches in thickness and had a specific gravity of approximately 1.0. They were not easily shattered, had excellent cohesiveness and yet were not too hard to be readily eaten. At the pressures employed in these first trials (200 to 500 pounds per square inch), good cohesion could not be obtained without the addition of 3 to 5

percent of moisture, which was most conveniently added as steam delivered throughout the feed mixture. However, even with the added moisture the material failed to cohere satisfactorily in the cake unless some binder was also added. A powdered corn dextrin that had been found to give excellent results as a binder in the manufacture of pellets was chosen for use with the alfalfa hay mixture. The use of as much as 8 percent of the dextrin made cakes that were too hard. A level of 4 to 6 percent of this binder was considered to give the best results.

Temperature and moisture appeared to be more important factors than pressure within the range of 200 to 500 pounds per square inch. If the temperature of the compressor fell below 100° C., it was not possible to obtain good cakes even at 6 minutes of compression. Two minutes seemed to be the minimum time required for cohesion of the feeds at the pressure obtained on this small press. A reduction in required time of compression could obviously be obtained by increasing the pressure.

With the Carver press all attempts to obtain a satisfactory cake with a timothy hay mixture failed. Increases in compression time up to 6 minutes, in binder up to 19 percent and in steam up to 10 percent were ineffective in making a satisfactory cake at a temperature of 120° C. and pressure of 500 pounds per square inch. The resulting product began to swell as soon as it was released from the mold, the stems of the hay tending to straighten out and to spring away from the main body of the feed mass.

In further attempts to compress the timothy hay mixture, use was therefore made of a larger experimental food press on which pressures of about 3,000 pounds per square inch could be obtained. The mold used with this press measured about 4 inches by 6½ inches and the thickness of the resulting bricks varied from 2¼ to 4 inches. However, it was not feasible to obtain a compressor temperature comparable to that used with the Carver press. All cakes were of necessity made with a compressor temperature of 53° C. Added moisture to the extent of 5 percent by weight was introduced as steam in the same manner as when alfalfa hay was used. Variations were made in the preheating of the feed, in the amount of binder used, in the amount of pressure, and in the time of compression. Cakes were made both with and without preheating of the feed, all other conditions remaining the same.

In these trials with the timothy hay mixture, pressures of 1,000 or 2,000 pounds per square inch were ineffective. Good cakes or bricks, however, could be obtained at 3,200 pounds per square inch, which was the maximum pressure available under the conditions prevailing at the time of these trials. A minimum compression time of 45 seconds was required for good cohesion. This time could undoubtedly have been reduced if the temperature of the press had been increased. Better results were always obtained with the

preheated feeds. It also appeared that the most satisfactory binding effect in the timothy hay mixture was obtained with corn dextrin at a level of 8 percent.

Even with a pressure of 3,200 pounds per square inch, 5 percent added steam, 8 percent dextrin, and 45 to 60 seconds of compression, bricks made at a temperature of 50° to 53° C., although they appeared good when first released from the press, tended to swell and pull apart as they cooled. If,

TABLE 1. COMPRESSION CONDITIONS OF RUSSIAN BRIQUETTES AND BELTSVILLE CAKES

Feed	Pressures used	Temp. of feed	Temp. of compressor	Time of of compression	Specific gravity	Comments
	lb./sq. in.	C.	C.	Sec.	grams/cc.	
Russian briquettes	3,500 to 5,800	55°	120°	30–45	1.25	Required soaking before they could be eaten.
Beltsville cakes						
(1) alfalfa hay mixture	500	50°	120°	120	1.00	Satisfactory
(2) timothy hay mixture	500	50°	120°	360		Unsatisfactory
	3,000	55°	53°	45	0.69 to 0.82	Satisfactory if cooled in retaining process.

however, they were allowed to cool under slight pressure in a holding or retaining press, they retained indefinitely the size and shape assumed when first released from the press. It is believed that the necessity for cooling the bricks under pressure would be obviated with the use of a higher temperature in the mold during compression.

Good cakes made from the timothy hay mixture and cooled in the holding press have had specific gravities ranging from 0.69 to 0.82. The consistency of bricks was such that they could be readily eaten without previous soaking. They were not, however, as resistant against shattering as bricks made from the alfalfa hay mixture at lower pressures. Table 1 summarizes the conditions used in making these cakes as compared with those of the Russian briquettes.

The results obtained in these trials suggest that the minimum amounts of pressure, heat, time and binder required for the production of satisfactory cakes from mixtures of roughages and concentrates depend greatly on the character of the roughages used. Although it was not possible, with the

available equipment, to reproduce exactly the conditions described for making the Russian cakes, from the results obtained it appears that the heat and pressure specified in these conditions represent the maximum or upper limit which would be required for the coarse roughages and that less heat and/or pressure will be required when the softer stemmed forages are used.

The space-saving advantages of a compressed complete diet are apparent in table 2, which presents the densities of various feeds in terms of pounds per cubic foot and of the volume occupied by one ton.

TABLE 2. COMPARATIVE DENSITIES OF SOME FEEDS

Feed	lb./cu. ft.	cu. ft./T.
German bale	45	45
Russian briquettes	77.9	25.7
Beltsville pellets	31 to 37	65 to 54
Beltsville cakes		
(a) with alfalfa	62.3	32
(b) with timothy	43 to 51	47 to 39
Ordinary baled hay	16.7	120
Double compressed hay	23.5 to 29.4	85 to 68
Heavy oats (38 lb./bu.)	30.5	66

Summary

A report is made of some exploratory trials in the compression of mixtures of chopped hay and whole grain into cakes suitable for feeding horses. The results indicate that the kind of forage used in the mixture is important in determining the conditions of temperature and pressure required for the production of satisfactory cakes. Cakes with a specific gravity of 1.0 were produced from an alfalfa hay mixture at a temperature of 120° C. with a pressure as low as 500 pounds per square inch. However, when timothy hay was substituted for alfalfa this pressure was inadequate even though the amount of binder was increased and the time of compression lengthened. Cakes with a specific gravity of 0.69 to 0.82 were produced from a timothy hay mixture at a temperature of 53° C. with a pressure of 3,000 pounds per square inch.

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MOTILITY PATTERNS OF THE CECUM OF THE HORSE

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DATA on the motor activity and functions of the cecum are very meager. Dukes (1947) states that the most important function of the cecum of herbivores appears to be that of a reservoir in which cellulose and other food constituents can soak and undergo bacterial fermentation. Elsden *et al.* (1946) found more volatile organic acids in the cecum than in the colon of recently killed horses. Cecal movements of most of the species that have been studied seem to be sluggish, indicating that ingesta would remain in that part of the digestive tract for comparatively long periods. Dukes (1936), using anesthetized horses, described waves beginning at the base of the cecum and traveling over the colon.

The experiments reported in this paper were undertaken to obtain information on the motility of the cecum in an intact animal. Data on the effect of different feeds and feeding methods were also recorded and were related to changes in the size and activity of the cecum.

Experimental

The experimental animal was a Percheron filly. A fistula was placed in the cecum when she was 14 months of age. She remained in good condition and gained weight over the period of time the fistula was present. Experiments with the fistula were performed over a period of a year.

Two balloons, twenty to thirty cc. in capacity and filled with air at atmospheric pressure, were used to record the activity of the cecum. One balloon was placed near the apex and the other near the base of the organ. They were attached to water manometers by means of hoses made from large stomach tubes. The activity was recorded on a long paper kymograph driven by a constant speed electric motor. The samples for pH determination were collected in a screw-topped jar, taken directly to the laboratory, and read on a Coleman pH meter. The activity of the cecum was measured both when the animal was allowed to eat and drink at will and under a standard schedule of feed and water. Records obtained under both conditions were similar, but the effects of feed and water were more concise under the standard schedule.

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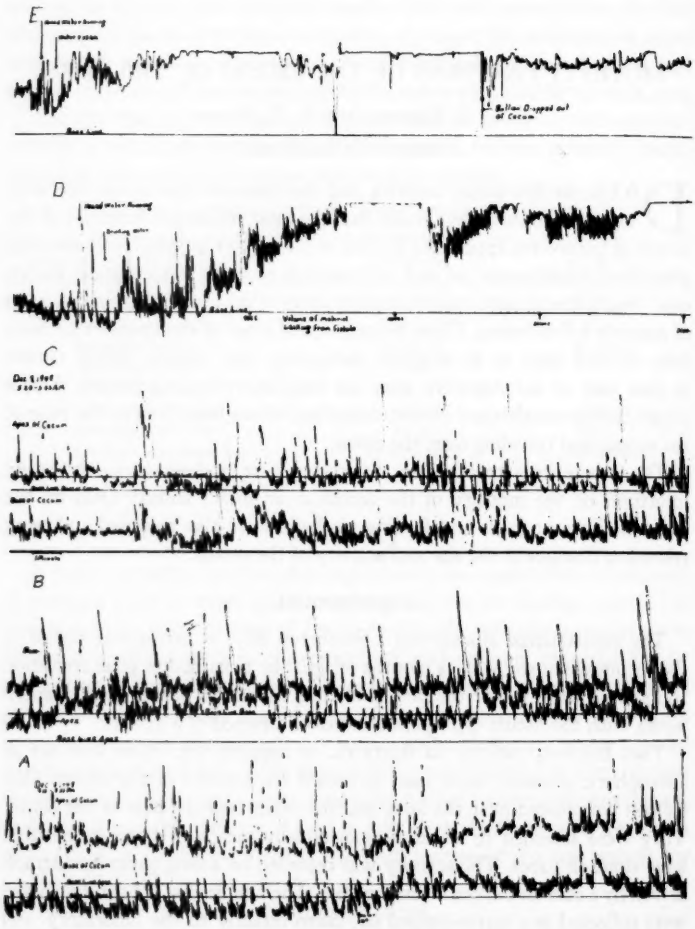

Figure 1. Motility patterns of the cecum. D. and E. Effect of drinking large amounts of water on the motility and tone of the apex of the cecum. C. Motility of the cecum 11–12 hours after feeding. B. Changes in tone of the apex of cecum. (7th hour after feeding.) A. Effect of water on change in tone of the cecum. (3rd hour after feeding.) (Note comparative tone of base and apex at various times after feeding.)

Results and Discussion

The cecum seemed to have a basic pattern of motility (figure 1). This pattern was divided into three parts. Large sharp contractions occurred which appeared to be peristaltic in nature. Interspersed between these were smaller ones that seemed to be local in nature. Superimposed on these two phases were large changes in tonus. All of these were related to the movement of feed and water through the digestive tract.

TABLE 1. MOTILITY OF THE CECUM: LARGE CONTRACTIONS

Time	Base			Apex			pH
	Contractions (per hour)	Contraction time (seconds)	Interval (seconds)	Contractions (per hour)	Contraction time (seconds)	Interval (seconds)	
6– 7 P.M.	32	7.6	108	48	6.6	69	7.1
7– 8 P.M.	39	7.3	85	61	7.4	52	7.4
8– 9 P.M.	40	6.3	84	46	7.2	70	6.7
*9–10 P.M.	53	6.7	59	71	6.3	44	6.6
10–11 P.M.	34	7.7	97	57	6.7	56	6.4
11–12 P.M.	46	9.5	69	55	8.9	56	6.3
12– 1 A.M.	34	8.6	97	44	9.8	72	7.4
1– 2 A.M.	31	8.7	109	52	7.6	62	6.8
2– 3 A.M.	32	7.7	103	42	7.4	79	
3– 4 A.M.	34	7.4	99	48	8.1	66	
4– 5 A.M.	30	7.6	114	35	7.6	96	
5– 6 A.M.	38	8.0	86	37	7.9	89	

* Animal drank 6.5 gallons of water at 9:27 P.M.

The large contractions moved over the cecum from the base to the apex and from the apex to the base. Some did not travel over the entire length of the organ. Sometimes they occurred as a back and forth movement in the following manner. A contraction of the apex was followed by another at the base and then still another at the apex. At times several contractions occurred consecutively at the apex, these being succeeded by one or two at the base. In general, more contractions occurred at the apex than at the base. They seemed to be a type that died out before reaching the base of the organ.

When the digestive tract contained food, contractions increased in frequency as well as in regularity (table 1). For the first six hours after feeding, the average contraction rate per hour of the base was 41, and for the next six, it was 33. During the same two periods, the average contraction rates for the apex were 56 and 43 per hour, respectively. The increase in frequency that occurred after feeding amounted to 19.5 percent for the base

and 23 percent for the apex, thus indicating a quantitative difference in the cecal activity depending on the presence of feed and water in the tract. Drinking water caused a definite increase in the frequency of contractions (table 1). When the upper portion of the digestive tract was relatively empty, the contractions had a tendency to occur in groups, two or three contractions occurring very close together with a period of inactivity following (figure 1C).

The average duration of these large contractions also varied at different times after feeding. For the base, the range from was 6.3 seconds between the second and third hours after feeding to 9.5 seconds between the fifth and sixth hours. For the apex, the time varied from 6.3 seconds between the third and fourth hours after feeding to 9.8 seconds between the sixth and seventh hours.

The rates at which the large contractions traveled along the cecum ranged from 4 to 30 cm. per second, with an average of 8 cm., as measured by the kymograph. Occasionally the cecum appeared to contract simultaneously in all regions. It is possible that these latter contractions were very rapid peristaltic rushes which the apparatus was not sensitive enough to record. Quantities of ingesta were moved along ahead of these rushes. After the animal drank water and the ingesta became more fluid, these contractions forcefully pushed the ingesta from the fistula.

Under a standard schedule (figure 1D and E) reflex activation caused large contractions at the apex. The animal was watered twice daily. Before the morning water was offered, the base line and rate of contraction of the apex were recorded. The animal was then permitted to hear water running from the tap. A few sharp contractions occurred immediately. This reflex activity, however, was less marked than that caused by the actual presence of water in the stomach.

The smaller contractions seemed local in nature, since those at the base showed no particular relation to those occurring at the apex. As seen at the fistula, they appeared as rolling movements of the wall of the cecum. Changes in the character of the movements were also related to the presence of feed in the digestive tract. They increased in frequency when ingesta were in the organ and decreased in frequency when the tract was relatively empty. Between the fifth and sixth hours after eating, the contractions again changed in appearance. The rolling motion decreased, although small local areas of the organ continued to contract. While this decrease was occurring, the larger contractions were becoming slower, thus indicating a change in the cecal activity. That these movements were capable of moving ingesta in the organ was shown by the fact that boluses continually worked out of the fistula when the cecum contained chyme. These boluses were small

and relatively dry. Their forward progress was slow compared to that of material forced from the fistula by the peristaltic contractions.

The tone of the cecum was quite variable, ranging from a negative pressure of 10 cm. of water to a positive one of 20 cm. That the tone may have been even higher was indicated by the fact that the pressure was great enough several times to force all the air from the balloon. In general, the tone at the apex was greater than that at the base, although the relative tone changed frequently from one region to another. The tone of the entire

TABLE 2. EFFECT OF FEED AND WATER ON CHANGES IN TONE OF THE CECUM

Time	Treatment	Tone cm. water	
		Base	Apex
5:50–6:00 P.M.	Feed 6:00 P.M.	− 5	4.0
6:00–6:10 P.M.		− 4	5.2
6:10–6:20 P.M.		− 4	7.2
6:20–6:30 P.M.		− 3	9.2
6:30–7:20 P.M.	Water 7:20 P.M.	− 4	5.0
7:25–7:40 P.M.		0	10.0
7:40–8:30 P.M.		− 4	8.0
8:30–9:27 P.M.	Water, 6.5 gal. at 9:27 P.M.	− 4	8.0
9:27–9:53 P.M.		3.6	13.2
5:45–6:00 A.M.	Feed, 6:00 A.M.	−10.0	− 1.6
6:00–6:15 A.M.		− 8.0	3.0
6:40–6:55 A.M.	Water, 6:50 A.M.	− 9.0	3.0
6:55–7:10 A.M.		− 6.8	6.6

organ increased after the animal ate and drank (table 2). When feed and water were offered at will, the changes were smaller but were of the same nature as the more marked ones that occurred when the animal was on a standard schedule. Figure 1D and E is a record of the effect of a large intake of water. Other records show that feeding the animal had a similar effect on the apex. In addition, simultaneous records taken of the activity of the base show that a smaller increase in tone but larger sharp contractions occurred at the base. The over-all effect of the feed and water caused a modification of the activity of the cecum and forced the partially digested products into the large intestine. All the records collected can best be explained by the assumption that the presence of feed or water in the stomach caused a reflex emptying of the cecum. In spite of the high tone found at the apex, water was forced from the fistula in large amounts after the animal had consumed large quantities. Accompanying the increase in tone and activity following the ingestion of feed or water, the mucosa of the cecal

wall seen at the fistula increased in vascularity, indicating an increased blood supply to the organ.

By the use of tracers, it was possible to follow the movement of partially digested feed through the cecum (table 3). Feed appeared at the fistula approximately one and one-half hours after the animal ate. The amounts leaking from the fistula increased through the third and fourth hours, then began to decrease so that most of the feed eaten at one time had passed

TABLE 3. TIME REQUIRED FOR FEEDS TO REACH THE CECUM

Ration	Time fed	Tracer	Appearance at fistula
Alfalfa hay Rolled barley	8:30 A.M.	Ground corn	10:00 A.M.
Alfalfa hay Rolled barley	9:00 A.M.	Ground corn	10:30 A.M.
Alfalfa hay Oat hay Rolled barley	9:05 A.M.	Chromic oxide	10:45 A.M.

through the cecum by the end of the sixth hour. Water moved through the tract very rapidly. The activity of the apex accompanying this movement through the cecum is shown in figure 1D. The amounts of fluid leaking from the fistula during six 5-minute intervals after the animal drank 7.8 gallons of water were 93 cc., 1,058 cc., 2,400 cc., 3,600 cc., 4,500 cc., and 485 cc., respectively.

The pH values of the material leaking from the fistula were related to the movement of food through the digestive tract (table 1). Samples taken at feeding time were essentially neutral. During the first hour there was an increase in pH, indicating a secretion of alkaline material by the glands of the intestine. During the next hour, when the feed previously eaten appeared at the fistula, the pH of the chyme became more acid, indicating the preponderance of acid secretion by the stomach. Between the sixth and seventh hours, after the bulk of the chyme from the previous feeding period had moved through to the large intestine, the pH of the chyme increased again. As the cecum emptied, the pH returned toward the neutral point.

Observations made during the experimental period indicated that leakage of partially digested material from the fistula was greater when the roughage was alfalfa hay than when it was oat hay. It was also observed that the

animal drank more water and consumed more salt when the roughage was alfalfa hay (table 4).

Records were kept to determine the differences in water and salt consumption on the two kinds of roughage. The experimental animal with the fistula was permitted to consume roughage at will. During the period on oat hay, she was not eating well, thus accounting for the low consumption of that roughage. In order to determine whether the increased water and salt consumption was due to the presence of a fistula, the experiment was repeated on a normal animal with the following variation. The total amount of roughage was held constant during the feeding trial. Since the alfalfa

TABLE 4. EFFECT OF KIND OF ROUGHAGE ON THE WATER AND SALT CONSUMPTION

Animal	Feed[1]	Amount consumed daily (lbs.)	Water consumed daily (lbs.)	Dry material consumed daily (lbs.)	Salt consumed daily (oz.)	Daily mean temperature (average)[2]
with fistula	oat hay	12.4	112.0	—	2.75	61.2° F.
	alfalfa hay	28.0	188.0**	—	6.25	65.2° F.
normal	oat hay	21.7	70.4	19.7	0.34	68.7° F.
	alfalfa hay	21.8	90.1**	18.8	0.57	72.2° F.

[1] Both animals received 5 pounds of rolled barley per day in addition to roughage.
[2] Average of the maximum and minimum daily temperatures.
** Significant at 0.01 level.

fed in this second experiment had a higher moisture content than oat hay, the intake of dry matter was less on the former. By analyses of covariance, the data for the first experiment were then corrected for the effect of the amount of feed eaten and the temperature, and those for the second (with the normal animal) for temperature only, since the amount of roughage was constant. In both experiments the amount of water consumed when the roughage was alfalfa was significantly greater than when the roughage was oat hay. Salt consumption was also greater when the roughage was alfalfa hay.

Since water has such a marked effect on the activity of the digestive tract, the differences observed on the alfalfa hay may possibly be explained by an indirect effect of the increased water consumption. In support of the above hypothesis, Olsson *et al.* (1949) found that grasses in the form of pasture moved through the digestive tract faster than the same grasses in the form of hay. Feces were more moist and the volume of urine excreted by the animal was greater when the roughage was alfalfa hay.

Summary

Motility studies of the cecum were conducted on a horse with a cecal fistula. The cecum appears to have a basic motility pattern which is modified by the presence of feed and water in the digestive tract.

Different roughages modify the motility of the cecum and water exerts a pronounced influence on the activity of the organ.

The patterns of activity suggest that the cecum acts as a reservoir for the partially digested feeds and its activity is coordinated to move ingesta on to the large intestine when more feed is eaten by the animal.

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THE INCIDENCE OF FEMALE GENITAL ABNORMALITIES IN SWINE[1,2,3]

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APPROXIMATELY one-fifth of the females in a swine herd fail to conceive during a breeding season and about one-third of all matings are infertile (Phillips and Zeller, 1941).

Warnick, Grummer and Casida (1949) reported that in a group of 63 "repeat-breeders" bilateral barriers to fertilization were present in 50.0% of the nonparous females (gilts) and 15.8% of the sows. In addition, unilateral abnormalities were present in 13.7% of the gilts and 15.8% of the sows. In a similar study of 79 animals Wilson, Nalbandov and Krider (1949) found that 35.3% of the gilts and 10.7% of the sows had gross abnormalities which made fertilization unlikely, and 17.6% of the gilts and 21.4% of the sows had other gross abnormalities although fertilization was judged possible. Tubal abnormalities, cystic ovaries and missing parts of the genital tract were the most common abnormalities found in both studies.

The "repeat-breeder" studies necessarily involved small, selected groups of animals. The study reported here was made to estimate the incidence of various gross abnormalities in a much larger, less selected group of females

Materials and Methods

A total of 5,088 slaughter-females was examined at a local packing plant for the presence of gross genital abnormalities. Samples of 300–350 animals were taken one day each week for four consecutive weeks during the months of January, April, July and October. All samples contained both packing and butcher hogs.

Carcass weights were obtained on all animals studied. Each animal was classified by the appearance of the nipples as nonsuckled or suckled and by manual palpation or visual appearance of the uterus as nonpregnant (open) or pregnant. Some animals in the very early stages of pregnancy were undoubtedly classified erroneously as open because the uteri were not examined internally.

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The data for purposes of analysis were divided into four seasons (months), five weight groups (carcass weights converted to approximate live weights) and four reproductive classes, i.e. nonsuckled-open, nonsuckled-pregnant, suckled-open and suckled-pregnant. The Chi-square test for homogeneity was used as a test of significance throughout.

Results and Discussion

Tubal abnormalities

Tubal abnormalities (hydrosalpinx and bursitis) were found in 1.4% of the animals studied (table 1); they were found in both open and pregnant

TABLE 1. EFFECT OF REPRODUCTIVE CLASS ON THE INCIDENCE OF TUBAL ABNORMALITIES AND CYSTIC FOLLICLES

Comparison	Reproductive class				Total or average	X^2
	Non-suckled		Suckled			
	Open	Pregnant	Open	Pregnant		
Number of animals	2967	531	1288	302	5088	
% with tubal abnormalities	1.8	0.6	1.2	0.0	1.5	10.5*
% with cystic follicles plus corpora lutea	0.6	1.5	1.9	2.3	1.1	18.1**
% with cystic follicles only	0.4	0.0	1.2	0.0	0.6	8.6**[1]

[1] Comparison made between nonsuckled-open and suckled-open classes.
* Significant ($P < 0.05$).
** Highly significant ($P < 0.01$).

animals. The overall differences in incidence in the four reproductive classes were significant but the difference between the nonsuckled-open and the suckled-open classes only was not significant. Thus these data as well as those of Warnick, *et al.* (1949) and Wilson, *et al.* (1949) fail to support the belief that tubal abnormalities arise principally as a result of infections contracted at the time of parturition. As a matter of fact a number of the affected animals in the nonsuckled-open class had genital organs that were not yet mature. The presence of tubal abnormalities in virgin gilts is in contrast with the views of Rowson (1942) who assumed that unbred heifers had had little chance of developing tubal abnormalities.

The incidence was significantly higher in the heavier animals than in the lighter animals (table 2). This was particularly true in the nonsuckled-open

TABLE 2. EFFECT OF BODY WEIGHT ON THE INCIDENCE OF TUBAL ABNORMALITIES AND CYSTIC FOLLICLES

Comparison	Weight—lbs.					Total or average	X^2
	<180	180–229	230–279	280–334	>334		
Number of animals	309	1326	1189	689	1575	5088	
% with tubal abnormalities	0.3	0.9	1.0	1.6	2.2	1.4	13.2*
% with cystic follicles plus corpora lutea	0.3	0.3	0.3	1.2	2.5	1.1	44.0**
% with cystic follicles only	0.3	0.2	0.6	0.0	1.6	0.6	24.0**

* Significant ($P < 0.05$).
** Highly significant ($P < 0.01$).

group and probably means that these animals were saved for breeding as gilts but were culled when they did not conceive; consequently they were heavier when marketed than they would have been, had they not been in the breeding herd for some time.

Seasonal differences in incidence of tubal abnormalities were highly significant (table 3). The incidence was highest in April and lowest in October. One explanation for the higher incidence in April would be that many of these animals were bred for spring farrow and were not suspected of being

TABLE 3. EFFECT OF SEASON ON THE INCIDENCE OF TUBAL ABNORMALITIES AND CYSTIC FOLLICLES

Comparison	Month				Total or Average	X^2
	January	April	July	October		
Number of animals	1299	1279	1170	1340	5088	
% with tubal abnormalities	1.1	2.8	1.1	0.5	1.4	28.2**
% with cystic follicles plus corpora lutea	1.9	0.9	0.9	0.7	1.1	10.8*
% with cystic follicles only	0.8	1.6	0.3	0.0	0.6	24.1**

* Significant ($P < 0.05$).
** Highly significant ($P < 0.01$).

open until the farrowing season approached. They were marketed when they were found to be open. Because a lesser number of sows are bred for fall farrow in Wisconsin the same situation would not exist in October.

Cystic follicles plus corpora lutea in ovaries

Animals having one or more follicles at least one inch in diameter were classified as cystic. Those with definite, well formed corpora lutea in addition to cystic follicles were considered separately from those having cystic follicles only. The former condition was found in 1.1% of the animals studied and ranged in incidence from 0.6% in the nonsuckled-open class to 2.3% in the suckled-pregnant class (table 1). The incidence was higher in suckled than in nonsuckled animals and in pregnant than in nonpregnant animals. The incidence was also significantly higher in the heavier animals (table 2). This suggests that the condition is associated with both parity and pregnancy, and also that "delayed culling" described above may be a cause of the differences. The incidence of cystic follicles plus corpora lutea was twice as high in January as in any other month while the incidence of the other cystic condition was highest in April. Since the incidence of both cystic conditions was lowest in October it might be assumed that cystic follicles tend to develop most frequently in late fall and early winter. It is possible that corpora lutea are usually present in the early stages of the cystic condition but tend to disappear later. Thus many of the animals discovered and marketed soon after the condition arose, i.e. in January, would have corpora lutea in addition to cystic follicles while the corpora lutea would have disappeared in many of the animals that were not sold until April.

Cystic follicles without corpora lutea

This condition was found only in open animals. In most cases no luteal tissue could be distinguished macroscopically but in a few cases luteinized "patches" were found in the wall of the cyst.

As was true of the other type of cystic condition, the incidence was higher in suckled than in nonsuckled animals (table 1) and was also higher in the heavier animals (table 2). This condition was most frequently found in April (table 3) probably indicating that these animals were not having heat periods and were consequently regarded as pregnant and not sold until farrowing time.

Missing parts of the genital tract

The incidence of missing parts of the genital tract is given in table 4. A detailed examination of the data did not show differences in incidence associated with reproductive class, weight or season so only the summary is presented.

Missing uterine horns and missing segments of uterine horns were the most common abnormalities in this category. In most cases they were unilateral and there was no obvious tendency for either the right or left horn to be "blind" or missing more frequently than the other. Unilateral missing parts were found about as frequently in suckled as in nonsuckled animals indicating that their presence on one side does not prevent pregnancy in the other horn. Their presence would, however, probably reduce litter size by about one-half since, with both ovaries present, no compensatory function of the ovary on the "complete" side could be expected. The evidence of Hammond (1921) and Corner (1923) shows that the number of pigs born is considerably less than the number of ova shed. If a lack of pregnancy in one horn would allow more than the usual percentage of ova to develop in

TABLE 4. INCIDENCE OF MISSING PARTS AND DOUBLE PARTS OF GENITAL TRACT IN 5088 ANIMALS

Abnormality	Percent incidence
Missing uterine horn	0.3
Missing segment of uterine horn	0.3
Missing vagina, cervix, and uterine horns; male ducts in broad ligament	0.02
Missing cervix	0.02
All reproductive organs except vulva missing	0.04
Double cervix	0.04
Double uterine horn	0.02
Total	0.72

the other horn, litter size would be reduced less than otherwise expected.

Other missing parts in the 5,088 animals studied were: one animal with no cervix, one animal with no cervix, vagina or uterine horns, and two animals with reproductive organs other than the vulva apparently completely absent. It should be pointed out that the method of collecting organs for examination did not permit a systematic check for the last mentioned abnormality (it should also be pointed out that the organs of intersexes had little chance of being picked up) and the condition may be more common than these results indicate.

Double parts

Only three animals with abnormal duplication of parts were found in the whole study. Two of these had double cervices and the other had a double section for about three inches in one uterine horn. All three animals were otherwise normal and one with a double cervix and the one with the double horn were classified as suckled indicating that these abnormalities did not prevent pregnancy.

Rudimentary male ducts

Rudimentary male ducts were found in the broad ligaments of 8.9% of the 3,476 animals examined for this condition (table 5). All of the animals in the April sample and a part in the January sample were excluded because this abnormality was not noted and classified consistently at those times.

Two classifications were made: complete ducts and incomplete ducts. The former extended unbroken along most of the length of the uterine horn; the

TABLE 5. EFFECT OF REPRODUCTIVE CLASS ON THE INCIDENCE OF INCOMPLETE AND COMPLETE MALE DUCTS

Comparison	Reproductive class				Total or average	X^2
	Non-suckled		Suckled			
	Open	Pregnant	Open	Pregnant		
Number of animals	1925	274	1054	223	3476	
% with incomplete structures	7.6	4.0	4.7	3.0	6.1	16.7**
% with complete structures	3.1	3.2	2.5	0.8	2.8	4.8
Total %	10.7	7.2	7.2	3.8	8.9	

** Highly significant ($P < 0.01$).

latter were quite variable and ranged from dot-like structures extending for only a fraction of an inch to several fairly long sections extending almost the whole length of the horn. Each type occurred either unilaterally or bilaterally; the two types also occurred in combination, i.e. complete on one side and incomplete on the other. It is emphasized that the terms "complete" and "incomplete" are relative and that both types were really rudimentary structures.

The incomplete structures were more frequent in the nonsuckled than in the suckled animals and also more frequent in the open animals. These differences were highly significant. However the occurrence of the complete ducts was not significantly different in the four reproductive classes. It is interpreted that incomplete ducts tend to disappear or are more likely to escape detection during pregnancy because of thickening of the broad ligament while complete ducts are more likely to remain obvious.

It might be assumed that these ducts represent a degree of intersexuality and further that they would be associated with lowered fertility which could be expressed either by failure of the female to conceive or by reduced

litter size. If this were true it should be reflected by a higher incidence of the condition in the nonsuckled than in the suckled classes because the affected animals did not conceive; or by a higher incidence in the suckled-open class than in the suckled pregnant class because there should be a tendency for affected sows not to be rebred because of reduced litter size. However in the more extreme kind, the "completes," the differences in incidence in the different reproductive classes were not significant, which fails to bear out the hypothesis.

Immature genital organs

More than one-fourth of the nonsuckled-open class of animals had immature genital organs. These animals are included in all calculations but if they were not included the percentages of the various abnormalities in this class would be increased by about one-third. A detailed report of this condition will be presented separately.

Discussion

About 5.1% of the post-puberal, open gilts and 4.9% of the open sows examined had gross genital abnormalities; this is exclusive of rudimentary male ducts which did not appear to have a marked effect on fertility. If this sample of animals is considered to represent a typical breeding population of which one-fifth would fail to conceive during a breeding season and if it is assumed that gilts and sows do not differ in reproductive efficiency, i.e. the same proportion of each group fail to conceive, then about 26% of the breeding failures in gilts and 25% of the failures in sows could be attributed to gross genital abnormalities. Exclusion of unilateral abnormalities would make these figures slightly lower. Since Phillips and Zeller (1941) did not distinguish between gilts and sows no estimate of the relative breeding efficiency of the two groups is available.

The estimate of 26% in gilts is considerably lower than the percentages of abnormalities reported by Warnick, *et al.* (1949) (50.0% bilateral, 13.7% unilateral) and by Wilson, *et al.* (1949) (35.3% fertilization unlikely, 17.6% fertilization possible). This indicates either that the samples of gilts used in the "repeat-breeder" studies contained more than the usual proportion of animals that fail to conceive because of genital abnormalities or, more likely, the true proportion of gilts that fail to conceive from all causes is less than 20%. Indeed if only 10% of the post-puberal gilts in a breeding herd fail to conceive during a breeding season then 50% of the breeding failures could be attributed to gross genital abnormalities. The estimate of 25% of the breeding failures in sows being due to genital abnormalities does not differ greatly from findings of Warnick, *et al.* (1949) (15.8% bilateral, 15.8%

unilateral) and Wilson, *et al.* (1949) (10.7% fertilization unlikely, 21.4% fertilization possible). Thus these data when considered in view of the findings of the "repeat-breeder" studies suggest that reproductive failures are less common in gilts than in sows. This point is important and should be studied.

Summary

The incidence of gross genital abnormalities was studied in 5,088 gilts and sows at a local packing plant. The incidences of various abnormalities were: tubal abnormalities (bursitis and hydrosalpinx), 1.4%; cystic follicles plus corpora lutea, 1.1%; cystic follicles without corpora lutea, 0.6%; missing parts, 0.7%; double parts, 0.1%; and rudimentary male ducts (computed on 3,476 animals), 8.9%. The incidence of tubal abnormalities and of both types of cystic ovaries varied significantly with reproductive history and weight of the animal and with season of the year. The incidence of missing parts and double parts was not associated with these factors. The incidence of male ducts was not significantly associated with reproductive history of the animal.

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THE EFFECT OF SEASON OF BIRTH ON SEXUAL DEVELOPMENT IN GILTS[1,2,3]

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IN A preliminary report Wiggins, Casida and Grummer (1948) stated that a considerable proportion of gilts had not reached puberty when slaughtered at usual market weights and that the percentage of juvenile animals varied considerably at different seasons of the year. The details of this study are presented in the present paper.

Phillips and Zeller (1943) reported that 24 small type Poland China gilts, checked daily for estrus from weaning to puberty, ranged from 160 to 259 days of age at first estrus and that 39 large type gilts ranged from 159 to 249 days. The mean ages and mean weights at first estrus were 207.8 days and 189.5 pounds for the small type gilts and 198.7 days and 199.3 pounds for the large type gilts. If the animals in this study were fairly representative of swine in general it would appear that the average age at puberty in gilts is approximately 6½ or 7 months and that some gilts do not reach puberty until they are considerably older.

Since gilts must be bred at about 8 months of age in order to farrow as yearlings it is important that the majority of gilts in a herd reach puberty by that age. Also if for any reason reproductive efficiency should prove to be lower in gilts bred at the first heat period than in gilts bred at subsequent heat periods, i.e. if reproductive efficiency should increase with advancing sexual age, it would be desirable that gilts intended for breeding should reach puberty considerably before 8 months of age.

This study was made to ascertain the stage of sexual development in gilts of different weights and ages at different seasons of the year.

Results

Studies of market gilts of unknown ages

The genital organs of 2,967 open gilts (nonparous) were examined at a local packing plant. Details of the procedure of collecting the organs are described elsewhere (Wiggins, *et al.*, in press). The ages of these animals were not known but their live weights were estimated from the weights of

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their carcasses. Animals which did not have corpora lutea in their ovaries were classified as sexually immature (juvenile or pre-puberal). In most cases the juvenile animals had very small reproductive tracts but some had tracts almost as large as those usually found in post-puberal gilts.

More than one-fourth of all animals examined were sexually immature at slaughter (table 1). As would be expected the incidence of the juvenile condition was much higher in the lighter animals, ranging from 49.8%

TABLE 1. EFFECT OF SEASON OF SLAUGHTER ON THE PERCENTAGES OF JUVENILE ANIMALS

Estimated live weight, pounds	January		April		July		October		X^2
	No. animals	% Juvenile	No. animals	% Juvenile	No. animals	% Juvenile	No. animals	% Juvenile	
Less than 180	81	45.7	82	30.5	35	48.6	89	74.2	33.7**
180–229	276	14.9	237	16.9	129	43.4	509	67.6	282.1**
230–279	242	14.0	237	11.4	84	20.2	284	56.3	171.0**
280–334	115	10.4	128	9.4	52	5.8	31	22.6	5.3
335 and more	60	9.1	137	4.6	116	0.9	43	2.3	6.7
Unweighted Mean.	—	18.8	—	14.6	—	23.8	—	44.6	—

** Highly significant (P = <0.01).

in animals weighing less than 180 pounds to 3.7% in those weighing 335 pounds and more. The seasonal differences were very pronounced. The average incidence was lowest in April (14.6%); it increased to 23.8% in July, rose sharply to 44.6% in October and decreased to 18.8% in January. Chi-square tests of homogeneity show that seasonal differences in the proportion of juvenile animals are highly significant in the three lightest weight groups but are not significant in the two heaviest weights.

The high percentage of sexually immature animals in October is of special interest. Of all animals weighing between 180 and 280 pounds, which would be comparable to the majority of the breeding gilts in the average herd, more than half had not reached puberty only a few weeks before the beginning of the fall breeding season.

If it is assumed that gilts slaughtered in the different months were about the same age at the time of slaughter (gilts slaughtered in October would be about the same age with respect to the spring farrowing season as those slaughtered in April with respect to the fall farrowing season) it would appear that season of farrow has an influence on the age of puberty. While little is known about the effect of season of birth on the attainment of puberty in mammals it has been demonstrated in chickens (Upp and Thomp-

son, 1927) and in pigeons and doves (Riddle, 1931) that season of hatch has a pronounced effect on the age at sexual maturity, i.e. at laying of the first egg.

Studies of gilts of known ages

After the above study was completed various Wisconsin farmers made available to us 113 gilts of known ages for study at the packing plant. The farrowing dates of these gilts were fairly uniformly distributed from February 12, to May 20, a range of 98 days. The animals were slaughtered between September 14 and December 13 at ages ranging from 180 to 250 days. Animals farrowed on or before April 2 (the mid-point of the range of farrowing dates) comprised the early farrowed group, and those farrowed after April 2 comprised the late farrowed group.

TABLE 2. EFFECT OF SEASON OF BIRTH ON ATTAINMENT OF PUBERTY IN GILTS

Date of farrow	No. of animals	Ave. age at slaughter (days)	Percent of all animals with juvenile reproductive organs	Percent of post-puberal animals having 2 or more sets of corpora lutea
Feb. 12 to April 2	61	221	57.4	57.7
April 3 to May 20	52	205	25.0	51.3

About 42% of the animals had not reached puberty at the time of slaughter (table 2). However 57% of those farrowed early were immature as contrasted with only 25% of those farrowed late although the latter group averaged 16 days younger at slaughter. The highly significant difference in the percentage of immature animals in the two groups cannot be accounted for on the basis of one group containing a preponderance of animals that had just barely reached puberty because the proportion of post-puberal animals having two or more sets of corpora lutea was not greatly different in the two groups.

Discussion

Smith (1937) states that first estrus usually occurs in gilts at about five months of age and Rice (1942) gives a range of three to six months. The data presented here as well as those of Phillips and Zeller (1943) indicate that the average gilt reaches puberty considerably later than this.

The present data show that gilts born in the spring (the natural farrowing season) are slower to reach sexual maturity than those born at other seasons

of the year. This finding is very similar to those of Upp and Thompson (1927) and Riddle (1931) who showed that birds hatched in the normal hatching season are slower to reach sexual maturity than those hatched at other seasons.

A large percentage of the pigs farrowed each year is from gilts; an exhaustive study of the factors influencing age at first estrus, therefore, would appear to be justified. It would be worthwhile to study the reproductive efficiency of gilts of different sexual ages, i.e. bred for the first time at different intervals after puberty.

Summary

The stage of sexual development was investigated in 2,967 market gilts of unknown ages slaughtered at four seasons of the year and in 113 gilts of known age slaughtered in the fall. Highly significant seasonal differences in the percentages of pre-puberal animals were found in the one study with the highest percentage being found in October and the lowest in April. In the other study the percentage of sexually immature animals was significantly higher in the group born early in the spring farrowing season than in the group born late although the latter group was younger at slaughter.

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THE EFFECT OF ADDING APF SUPPLEMENTS AND CONCENTRATES CONTAINING SUPPLEMENTARY GROWTH FACTORS TO A CORN-SOYBEAN OIL MEAL RATION FOR WEANLING PIGS[1]

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CERTAIN natural feed supplements as well as various commercially prepared vitamin concentrates contain supplementary growth factors for pigs. Neumann *et al.* (1948) reported that the growth rates of baby pigs on a purified diet were significantly increased by the injection of 0.1 ml. reticulogen per pig per day (20 units anti-pernicious anemia liver extract). Since this response was comparable to that produced by the injection of 2 mcg. of vitamin B_{12} per pig per day, it was suggested that vitamin B_{12} was the factor in reticulogen causing the increase in the rate of gain. Neumann *et al.* (1950) reported that 23 mcg. of vitamin B_{12} activity (fed as a concentrate) per pound of dry matter in the diet gave optimum growth of baby pigs fed a purified ration.

Kraybill (1947) reported an increase in the growth rate of pigs when meat scraps was included in the ration. This improvement was attributed to an unidentified factor in the meat scraps. Similar responses in weanling pigs were reported by Dyer *et al.* (1949) and in poultry by Hill (1948). Dried whey product improves the rate of gain beyond that produced by meat scraps indicating that the supplementary growth factor in the dried whey is different from that found in meat scraps. Krider *et al.* (1949) obtained significant increases in the growth rates of weanling pigs when either 2 or 4% dried whey product were added to a corn-soybean oil meal ration that contained 5% meat and bone scraps. These data are substantiated by those reported by Dyer *et al.* (1949) for the weanling pig when 2% of this product was fed and by Hill (1948) for the chick.

Reports from the Michigan, Iowa, Florida, New York, Missouri, Texas

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[3] Animal Science Department, Urbana, Illinois. The assistance of R. H. McDade, Swine Herdsman, and his coworkers in conducting these experiments is greatly appreciated.

and Illinois Stations show that the growth rate of pigs is increased by the addition of various feeds and certain APF supplements to certain rations (Anderson and Hogan, 1949; Burnside *et al.* 1949; Catron and Culbertson, 1949; Cunha *et al.*, 1949, 1949a; Dyer *et al.*, 1949; Hale and Lyman, 1949; Krider and Terrill, 1950; Lepley *et al.*, 1949; Luecke *et al.*, 1949, 1949a; Neumann *et al.*, 1949, 1950; Willman and Noland, 1949).

Objects of Experiments

The objects of these growth tests with weanling pigs fed in drylot were as follows:

Experiment 1. The purpose was to study the effect of reticulogen on the

TABLE 1. RATIONS FED TO WEANLING PIGS IN GROWING-FATTENING EXPERIMENTS I AND II (SPRING 1949)

Ingredients	Experiment number						
	I		II				
	Lot numbers		Lot numbers				
	1	2	1	2	3	4	5
	Basal[1]	Basal +1 ml. reticulogen[2]	Basal[3]	Basal +4% dried whey product with whey fermentation solubles	Basal +5% meat scraps	Basal +1.1% Lederle's APF supplement[4]	Basal +.05% Merck's APF supplement[5]
	Percent						
Ground yellow corn	63.5	63.5	63.5	60.0	62.0	61.9	63.5
Soybean oil meal, blended[6] (expeller)	34.0	34.0	34.0	33.5	26.5	34.5	34.0
Dried whey product with whey fermentation solubles	—	—	—	4.0	—	—	—
Meat scraps (55% protein)	—	—	—	—	5.0	—	—
Mineral mixture (H & K)[7]	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin A and D oil	0.5	0.5	0.5	0.5	0.5	0.5	0.5
APF supplement (Lederle's)	—	—	—	—	—	1.1	—
APF supplement (Merck's)	—	—	—	—	—	—	.05
Reticulogen (1 ml. per pig per week—injected)	−	+	−	−	−	−	−
B-vitamin additions	+	+	+	+	+	+	+

[1] 150 mg. thiamine, 150 mg. riboflavin, 500 mg. niacin, 600 mg. pantothenic acid, 150 mg. pyridoxine, 25 g. choline, 50 mg. folic acid, 82 mg. para-aminobenzoic acid and 8.2 g. inositol were added per 100 pounds of ration.

[2] 1 ml. (20 units anti-pernicious anemia liver extract) injected intermuscularly per pig per week.

[3] Same as 1 without para-aminobenzoic acid and inositol.

[4] Contained 3–4 mcg. vitamin B_{12} activity per gram by chick assay.

[5] Contained 12.5 mg. vitamin B_{12} activity per pound (LLD assay).

[6] Composed of equal parts of 42% crude protein expeller soybean oil meal from three sources.

[7] Mineral mixture reported by Krider *et al.* (1946) JOURNAL OF ANIMAL SCIENCE 5: 256.

growth rate of weanling pigs fed a corn-expeller soybean oil meal ration fortified with minerals, vitamins A and D and 9 vitamins of the B complex (table 1).

Experiment 2. The object was to compare dried whey product with whey fermentation solubles, meat scraps and certain APF supplements as sources of supplementary growth factors for weanling pigs.

Experiment 3. The object was to study (1) the effect of adding choline chloride with and without APF supplement to a corn solvent soybean oil meal ration including six B-complex vitamins; (2) the effect of adding an APF supplement with and without choline; (3) the effect of adding different APF supplements; and (4) the effect of adding dried whey product with whey fermentation solubles and whey yeast when choline and APF supplement were also added to the basal ration for weanling pigs fed in drylot.

Experimental Procedure

Experiment 1. Two comparable lots of ten 56-day-old Duroc pigs each were self-fed a 20% crude protein corn-expeller soybean oil meal ration in drylot. In addition, pigs in Lot 2 were injected, intramuscularly, with 1 ml. reticulogen (20 units anti-pernicious anemia liver extract) per pig per week. Pigs in experiments 1 and 2 were fed to final weights of 75 pounds each, while those in experiment 3 were fed to a final weight of 100 pounds. They were bedded with wood shavings, confined in pens with concrete floors, and given water *ad libitum*.

Experiment 2. Five comparable lots of ten 56-day-old Duroc pigs were self-fed in drylot. The smaller pigs (approximately 27 pounds average initial weight) were selected for this test. The basal ration as shown in table 1 was supplemented as follows: Lot 2, 4% dried whey product with whey fermentation solubles; Lot 3, 5% meat scraps; Lot 4, 1.1% Lederle's APF supplement; and Lot 5, .05% Merck's APF supplement.

Experiment 3. Six comparable lots of pigs were self-fed in drylot (concrete floors). They had been raised to weaning by sows fed adequate rations on bromegrass-red clover pasture. The smaller pigs averaging about 29 pounds were selected for this test. The basal ration fed to Lot 1 was the same as the one fed to Lot 1, Experiment 2 (table 1) except that blended solvent soybean oil meal was used and choline chloride was omitted. After the solvent soybean oil meal was extracted it was conditioned by heating to 135° to 220° F. for about 30 minutes to remove the solvent. Then it was toasted for 60 minutes at temperatures ranging from approximately 205° F. at the start to a maximum temperature of 230° F. The supplements added to the basal ration were as follows: Lot 2, 250 mg. choline chloride per pound of ration; Lot 3, 0.1% Merck's APF supplement; Lot 4, same as Lot 2 plus

0.1% Merck's APF supplement; Lot 5, same as Lot 2 plus 0.7% Lederle's APF supplement to add approximately the same amount of vitamin B_{12} activity as was added to Lot 4; and Lot 6, same as Lot 4 plus 3% dried whey product with whey fermentation solubles and 1% whey yeast.

When the APF supplements were added to the basal ration, they replaced an equal amount of ground yellow corn. Ration 6 was the same as ration 4 except that it contained only 60.9% ground yellow corn and 32.5% of solvent soybean oil meal.

Results and Discussion

Experiment 1. Pigs fed the basal ration including 9 vitamins of the B complex gained as rapidly as those receiving an identical ration that were injected with 1 ml. reticulogen per pig per week (equivalent to approximately 2.7 gamma vitamin B_{12} per pig daily). It is unlikely that pigs used in this experiment had large stores of vitamin B_{12} because their dams, since weaning, had received a ration composed of ground yellow corn, expeller soybean oil meal, minerals, vitamins A and D, and 6 vitamins of the B-complex, plus 4% penicillium meal. The penicillium meal did not increase the growth rate. In another test, by Dyer and Krider (1950) the rate of gain of weanling pigs was not increased when choline chloride was added to a similar ration which contained solvent soybean oil meal and 0.1% of a vitamin B_{12} concentrate.[4] Since no growth response occurred it is suggested that these pigs receiving the 9 vitamins of the B-complex, including a high level of choline (.18%), may have synthesized sufficient vitamin B_{12} to supplement the ration, or more likely that the amount of reticulogen injected was too low to promote a maximum growth response although this level per pig daily promoted excellent growth of baby pigs (Neumann, *et al.*, 1948). A vitamin B_{12}-choline relationship exists in which B_{12} and choline each have a sparing effect on the other, according to results obtained with chicks by Schaefer *et al.* (1949). No marked difference in either the uniformity of the pigs or the amount of feed required per 100 pounds gain was observed (table 2).

Experiment 2. The corn-expeller soybean oil meal ration including 7 vitamins of the B Complex (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, choline and folic acid) was improved slightly by the addition of 4% dried whey product with whey fermentation solubles. In another test at the Illinois Station 2% of this product produced a similar response over the basal ration (Dyer *et al.*, 1949). Meat scraps (55% crude protein) fed as 5% of the ration increased the average daily gain 0.13 pound per pig daily over that produced by the basal ration. It is suggested that this re-

[4] Merck's APF Supplement No. 3 containing 12.5 mg. vitamin B_{12} activity per pound.

TABLE 2. RESPONSE OF WEANLING PIGS FED A 20% CRUDE PROTEIN CORN-EXPELLER SOYBEAN OIL MEAL RATION TO RETICULOGEN, DRIED WHEY PRODUCT, MEAT SCRAPS AND APF SUPPLEMENTS (SPRING 1949)

	Experiment number						
	I		II				
	Lot numbers		Lot numbers				
	1	2	1	2	3	4	5
Comparison	Basal (including 9 B-vitamins)[1]	Basal +1 ml. reticulogen per pig per week[2]	Basal (including 7 B-vitamins)	Basal +4% dried whey product with whey fermentation solubles	Basal +5% meat scraps	Basal +1.1% Lederle's APF supplement	Basal +.05% Merck's APF supplement
Number of pigs	10	10	10[3]	10[3]	10[3]	10	10[3]
Av. initial weight, lb.	30	30	27	26	28	26	28
Av. final weight, lb.	75	74	80	74	78	77	75
Av. daily gain, lb. and standard error	1.09± .05	1.04± .04	1.15± .07	1.24± .06	1.28± .05	1.35± .05*	1.21± .06
Av. daily feed per pig, lb.	3.14	2.84	3.05	3.21	3.61	3.72	2.99
Feed per 100 lb. gain, lb.	292	280	272	263	285	277	256

* Pigs gained significantly faster($P \leqq .05$) than those in Lot 1, Experiment 2.

[1] See [1], Table 1.

[2] See [2], Table 1.

[3] An enteric disorder in the latter part of the test reduced the number of pigs per lot to 6. Only data on unaffected pigs are reported.

sponse was due to the animal protein factor(s) in the meat scraps and the response from the whey product was from factor S which is now believed to be a fraction of the animal protein factor. The feed required was slightly reduced when the dried whey product was fed but the reverse was true when meat scraps was fed.

The rate of gain was significantly improved ($P \leqq .05$) when 1.1% Lederle's APF supplement[5] (3.4 mcg. vitamin B_{12} activity per gram) was added to the ration. Since this product produced an excellent rate of gain (1.35 pounds per pig daily) and no enteric disorders occurred it is suggested that either it contains a supplementary growth factor other than vitamin B_{12}, or has an antibiotic property, or both. In another test at this station a similar improvement was observed when 1% of this product was fed (unpublished data). The addition of .05% Merck's APF supplement (12.5 mg. vitamin B_{12} activity per pound) increased the growth rate although not significantly

[5] This product is described as a dried fermentation product obtained by culturing a streptomyces on a medium adapted to the production of animal protein factor together with diatomaceous earth. It contains approximately 4.2 mg. aureomycin per gram (courtesy Dr. T. H. Jukes, Lederle Laboratories).

so. The feed required per 100 pounds gain in lot 5 was only 256 pounds, a 7% decrease as compared to the basal ration.

Experiment 3 is summarized in table 3. Choline chloride did not improve the basal ration containing solvent soybean oil meal for growth or feed efficiency with or without Merck's APF supplement. This confirms the results of Dyer and Krider (1950) which showed that choline chloride did

TABLE 3. RESPONSE OF WEANLING PIGS TO SOURCES OF APF IN CORN-SOLVENT SOYBEAN OIL MEAL RATIONS (EXPERIMENT III, FALL 1949)

	Lot numbers					
	1	2	3	4	5	6
Comparison	Basal	Basal +250 mg. choline chloride	Basal +0.1% Merck's APF[2]	3+250 mg. choline chloride per pound	2+0.7% Lederle's APF[3]	4+3% dried whey product with whey fermentation solubles and 1% whey yeast
Number of pigs	8	8	8	8	8	6
Av. initial weight, lb.	29	30	30	30	29	30
Av. final weight, lb.	99	100	100	100	101	101
Av. daily gain, lb. and standard error	1.17±.07	1.10±.04	1.23±.06	1.30±.04**	1.48±.04**[1]	1.35±.04**[1]
Av. daily feed per pig, lb.	3.25	3.29	3.59	3.76	4.01	3.95
Feed per 100 lb. gain, lb.	282	301	296	291	274	293

** Pigs in Lots 4, 5, and 6 gained very significantly faster ($P \leq 0.01$) than those in Lot 2, while pigs in Lot 5 also gained very significantly faster than those in Lot 4 (odds 118:1).

[1] Pigs gained significantly faster ($P \leq 0.05$) than those in Lot 1.

[2] Merck's APF supplement No. 3, 12.5 mg. vitamin B_{12} activity per pound (LLD assay).

[3] Lot 8108–1009, Lederle's APF supplement No. 5 (3 to 4 mcg. vitamin B_{12} activity by chick assay).

not help in the presence of Merck's APF supplement when either solvent or expeller soybean oil meal was fed in the ration. Choline chloride plus Merck's APF supplement fed as 0.1% of the ration produced slightly but not significantly faster growth than 0.1% Merck's APF supplement without choline (Lot 3 versus 4).

Ration 2, which was fortified with thiamine, robiflavin, niacin, calcium pantothenate, pyridoxine, folic acid and choline chloride, was very significantly ($P \leq 0.01$) improved for growth by additions of the various APF supplements (Lots 4, 5 and 6). Feed efficiency was not improved except in Lot 5 where Lederle's APF supplement was fed. This lot of pigs required about 5% less feed per pound of gain than the basal lot and about 9% less feed per pound of gain than Lot 2.

Pigs fed Lederle's APF supplement gained very significantly faster than those fed an equivalent amount of vitamin B_{12} activity from Merck's APF

supplement (Lot 4) suggesting either that the former supplement contains an unidentified factor or factor(s) of the APF complex needed for maximum growth or that the residual aureomycin in it has a beneficial effect on growth. This growth response confirms the results obtained by Burnside *et al.* (1949) and Cunha *et al.* (1949).

All lots fed the APF supplements received a higher level of vitamin B_{12} than has been found to be required for optimum growth of the baby pig (Nesheim, Krider and Johnson, 1950).

Summary

Three tests are reported in which weanling pigs were fed a 20% crude protein corn-soybean oil meal basal ration in drylot. The intramuscular injection of 1 ml. reticulogen per pig per week did not improve the rate of gain over that produced by pigs not receiving the reticulogen treatment when 9 vitamins of the B complex were included in the basal ration. The basal ration including expeller soybean oil meal and 7 vitamins of the B complex was improved although not significantly so by either 4% dried whey product with whey fermentation solubles, 5% meat scraps or .05% Merck's APF supplement, while the addition of 1.1% Lederle's APF supplement significantly improved the rate of gain.

When the basal ration contained solvent soybean oil meal, growth rate was not improved by the addition of either choline chloride or Merck's APF supplement. The latter supplement and all other sources of APF very significantly increased growth rate when choline chloride was also added to the ration. Pigs fed Lederle's APF supplement gained significantly faster than pigs fed an equivalent amount of vitamin B_{12} activity from another APF supplement, suggesting either the presence of an unidentified factor (or factors) or a beneficial growth response from the residual aureomycin in the former supplement. Feed efficiency was not improved by any of the supplements except the Lederle's APF supplement which showed a saving of 5% over the basal group and a saving of 9% over Lot 2 (basal ration plus choline). Dried whey product with whey fermentation solubles and whey yeast improved growth slightly, though not significantly, when fed in addition to Merck's APF supplement and choline chloride, suggesting that it may also contain the unidentified growth factor(s).

The feed efficiency was satisfactory in all experiments ranging from 256 to 301 pounds of feed per 100 pounds gain.

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COMPARISONS OF PASTURES AND SUPPLEMENTS FOR GROWING-FATTENING PIGS

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GROWING-FATTENING pigs on bromegrass pasture reached market weight one week later and required about 6% more concentrates per unit of gain than pigs fed similarly on alfalfa pasture, according to a preliminary report from the Illinois Station (1948). The details of this comparison and of alfalfa versus bromegrass-alfalfa pasture are reported herein.

Robison (1941) reported that toasted solvent soybean oil meal fed as the only supplement or in combination with other protein supplements produced a slightly faster rate of gain than did expeller soybean oil meal for growing pigs, while Hostetler and Boling (1936) and others have reported that these meals produced about the same average daily gains. Dyer and Krider (1950) found that heated solvent soybean oil meal was superior to expeller soybean oil meal in promoting gains on weanling pigs in drylot when fed in mixed rations equated to contain 20% crude protein. Average feed efficiency was about the same although the daily feed consumption per pig was somewhat greater when the rations contained the solvent soybean oil meal. The comparative palatability of solvent and expeller soybean oil meals when fed free-choice to self-fed pigs on pasture has not been studied.

Properly heated soybean oil meal is so palatable to pigs weighing 50 pounds or more that they will usually eat more than is needed to balance the ration when it is self-fed free-choice on pasture with grain and minerals. This excess consumption can be prevented by hand-feeding the proper amount of soybean oil meal, by mixing it into a ground balanced ration, or by mixing it with some less palatable feed. A supplement composed of 1 part of a mineral mixture and 5 parts of soybean oil meal was recommended by Vestal (1942). Other methods of using soybean oil meal in supplemental mixtures that can be self-fed on pasture have been suggested but have not been tested experimentally, except that it has been used up to 50% of the protein supplement along with animal or fish by-products.

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[2] Animal Science Department, Urbana, Illinois. These investigations were supported, in part, by the donation of funds and products to the University of Illinois by the A. E. Staley Manufacturing Company, Decatur, Illinois, Central Soya Company, Fort Wayne, Indiana, and Hiram Walker and Sons, Inc., Peoria, Illinois.

Wilford (1948) reported that 68 pound pigs self-fed a supplement composed of 80% soybean oil meal and 20% dried corn distillers' solubles with corn and minerals free-choice on alfalfa pasture made as rapid and somewhat more efficient gains than similar pigs fed the trio mixture as the supplement in drylot. Krider and Terrill (1949) found that the rate and efficiency of gains were not significantly affected when dried corn distillers' solubles replaced either meat and bone scraps or expeller soybean oil meal in a protein supplement composed of equal parts of meat and bone scraps and expeller soybean oil meal for growing-fattening pigs on bromegrass-alfalfa pasture.

Purpose

Over 400 growing-gattening pigs have been self-fed shelled yellow corn and minerals on various pastures from shortly after weaning to a final weight of 200 pounds to obtain practical information on: (a) bromegras versus alfalfa pasture; (b) alfalfa-bromegrass versus alfalfa pasture; (c) the value of expeller soybean oil meal as a supplement for pigs on bromegrass pasture; (d) solvent versus expeller soybean oil meal; (e) methods of feeding soybean oil meal; (f) the value of supplemental mixtures containing various ingredients such as expeller soybean oil meal, alfalfa meal, meat and bone scraps, and dried corn distillers' solubles; (g) meal versus pelleted supplement; and (h) the effect of night lights.

Experimental Procedure

Each lot of 14 to 25 pigs was given access to one acre of pasture. Shelled yellow corn and a mineral mixture (40% limestone, 40% steamed bone meal and 20% salt) were self-fed free-choice. The protein supplements were self-fed free-choice except in the experiments in which soybean oil meal was hand-fed.

The pigs were allotted on the basis of weight, litter, breed, sex and condition. Each group remained on test until the pigs had attained an average final weight of approximately 200 pounds. They were weighed individually at the start and close of the tests, and were usually weighed at bi-weekly intervals during the experiments.

The data on average daily gains for all experiments was analyzed statistically using the "t" test for unpaired differences (Snedecor, 1940). P values of 0.05 and 0.01 were considered significant, and highly significant respectively.

Results and Discussion

A. Bromegrass versus Alfalfa Pasture

The results of two experiments in which brome grass was compared

TABLE 1. BROMEGRASS VERSUS ALFALFA PASTURE FOR GROWING-FATTENING PIGS

Items compared	Experiment I, began May 31, 1945		Experiment II, began May 31, 1946	
Pasture	Alfalfa	Bromegrass	Alfalfa	Bromegrass
Supplement	Expeller soybean oil meal hand-fed once daily		Expeller soybean oil meal 200+alfalfa meal 100, self-fed	
(All lots self-fed shelled yellow corn and minerals free-choice)				
No. of pigs	14	14	16	16[2]
Days on test	109	116	122	129
Av. initial wt., lb.	52.9	53.1	49.3	49.2
Av. final wt., lb.	202.2	199.9	199.5	200.8
Av. daily gain, lb. (weighted)[1]	1.37	1.26	1.23	1.18
Av. daily feed:				
Shelled yellow corn, lb.	4.36	4.22	4.20	3.90
Soybean oil meal, lb.	.48	.48	.24	.46
Alfalfa meal, lb.	—	—	.12	.23
Minerals, lb.	.04	.04	.06	.06
Total, lb.	4.88	4.74	4.62	4.65
Feed per 100 lb. gain:				
Shelled yellow corn, lb.	318.0	335.1	341.3	331.8
Soybean oil meal, lb.	34.7	38.3	19.7	39.3
Alfalfa meal, lb.	—	—	9.9	19.7
Minerals, lb.	2.6	2.8	4.7	5.4
Total, lb.	355.3	376.2	375.6	396.2

[1] Difference in average daily gains between lots was not statistically significant. A weighted average daily gain as computed in these tests is based upon a summation of individual average daily gains for each pig divided by the no. of pigs per group.

[2] One pig removed.

with alfalfa pasture are summarized in table 1. Although the pigs fed on bromegrass gained slightly less per head daily than those on alfalfa pasture, the difference was not statistically significant. Pigs on alfalfa pasture reached market weight (200 pounds) approximately one week earlier than pigs on bromegrass. Pigs grazing bromegrass required 5.5% more feed per 100 pounds gain than those fed on alfalfa pasture. When the supplement was fed free-choice as in Experiment II, the pigs on alfalfa pasture ate 33% less supplement and 13% less minerals in producing 100 pounds of gain than pigs fed a similar ration on bromegrass pasture.

B. Bromegrass-Alfalfa Equal to Alfalfa Pasture

An average of two comparisons (table 2) shows that bromegrass-alfalfa

TABLE 2. BROMEGRASS-ALFALFA VERSUS ALFALFA PASTURE FOR GROWING-FATTENING PIGS

Items compared	Experiment III, began May 17, 1948		Experiment IV, began May 2, 1949	
Pasture	Bromegrass-alfalfa mixture	Alfalfa	Bromegrass-alfalfa mixture	Alfalfa
(All lots self-fed shelled yellow corn, minerals and supplement, free-choice)[1]				
Number of pigs	25	25	20	20
Days on test	111	111	112	112
Av. initial wt., lb.	40.5	40.9	36.2	36.3
Av. final wt., lb.	197.5	200.0	201.4	202.8
Av. daily gain, lb. (weighted)	1.43	1.45	1.47	1.48
Av. daily feed:				
Shelled yellow corn, lb.	4.35	4.48	4.59	4.57
Supplement, lb.[1]	0.43	0.35	0.53	0.52
Minerals, lb.	0.005	0.006	0.003	0.003
Total, lb.	4.78	4.84	5.12	5.10
Feed per 100 lb. gain:				
Shelled yellow corn, lb.	301.9	308.0	312.4	309.2
Supplement, lb.	30.0	24.0	36.0	35.3
Minerals, lb.	0.3	0.4	0.2	0.2
Total, lb.	332.2	332.4	348.6	344.7

[1] Experiment III: supplement contained 49.74% crude protein and was composed of equal parts of meat and bone scraps and expeller soybean oil meal.

Experiment IV: supplement contained 49.50% crude protein and was composed of equal parts of meat and bone scraps and solvent soybean oil meal.

pasture was fully equal to straight alfalfa pasture for growing-fattening pigs self-fed to a final weight of about 200 pounds. The rate of gain, average daily feed consumption per pig and fed required per 100 pounds of gain were nearly the same. This was true in Experiment III in which first year pastures were grazed as well as in Experiment IV in which second year pastures were used. More forage was provided than was consumed by either 20 or 25 pigs per acre in these tests. For example, on June 7, 1949 in Experiment IV, 2,630 pounds of bromegrass-alfalfa hay and 1,900 pounds of alfalfa hay were removed from the respective test lots. On July 14, 1949 an additional 840 pounds of bromegrass-alfalfa hay and 790 pounds of alfalfa hay were harvested from the respective pastures.

C. Soybean Oil Meal, Hand-Fed, versus No Supplement for Pigs on Bromegrass Pasture

The results in table 3 show that the pigs hand-fed expeller soybean oil meal once daily gained very significantly ($P \leqq 0.01$) more rapidly and reached

the final weight 26 days earlier than those not fed a protein supplement. From weaning to market, one ton of expeller soybean oil meal so fed saved 4,159 pounds of shelled corn plus 147 pounds of minerals.

Even from 116 pounds to market weight, pigs fed on bromegrass made very significantly more rapid ($P \leqq 0.01$) and more efficient gains when hand-fed expeller soybean oil meal than when no protein supplement was fed. During this period one ton of soybean oil meal hand-fed saved 4,333 pounds of shelled corn plus 190 pounds of minerals.

The pigs fed corn and minerals were not so well finished at 200 pounds as were those hand-fed soybean oil meal daily in addition to these feeds.

The bromegrass pastures remained green and succulent throughout the

TABLE 3. EXPELLER SOYBEAN OIL MEAL, HAND-FED, VERSUS NO SUPPLEMENT FOR PIGS FED ON BROMEGRASS PASTURE

(Experiment V began June 27, 1944)

Items compared	Weaning to market		125 pounds to market	
	Lot 1	Lot 2	Lot 1a	Lot 2a
	No supplement	Soybean oil meal hand-fed once daily[1]	No supplement	Soybean oil meal hand-fed once daily
(Each lot self-fed corn and minerals, free-choice, on one acre bromegrass pasture)				
Number of pigs	20	20	20	20
Days on test	139	112	41	28
Av. initial wt., lb.	39.8	39.8	129.1	116.4
Av. final qt., lb.	199.3	197.2	199.3	197.2
Av. daily gain, lb. (weighted)	1.15	1.40**	1.71	2.07**
Av. daily feed:				
Shelled yellow corn, lb.	3.98	3.91	6.53	6.26
Soybean oil meal, lb.	—	.46	—	.70
Minerals, lb.	.07	.05	.11	.06
Total, lb.	4.05	4.42	6.64	7.02
Feed per 100 lb. gain:				
Shelled yellow corn, lb.	346.6	278.6	381.8	303.3
Soybean oil meal, lb.	—	32.7	—	33.9
Minerals, lb.	5.9	3.5	6.2	2.8
Total, lb.	352.5	314.8	388.0	340.0

[1] Expeller soybean oil meal, 42% crude protein.

** $P \leqq 0.01$, very highly significant for Lot 2 over Lot 1, and for Lot 2a over Lot 1a.

summer until the close of the experiment. The bromegrass was palatable and withstood tramping remarkably well. One acre of it provided plenty of forage for 20 growing-fattening pigs even when no protein supplement was fed as in Lots 1 and 1a.

D. Methods of Feeding Expeller Soybean Oil Meal Singly or in Mixtures

When expeller soybean oil meal was self-fed free-choice (Lot 2, Exp. VI), the pigs ate almost twice as much per head daily as those hand-fed only enough soybean oil meal to balance the ration (Lot 1). The additional soybean oil meal consumed above ½ pound per pig daily in Lot 2 merely replaced part of the corn in the ration. Hand-feeding about ½ pound of soybean oil meal per head daily (table 4) provided enough supplemental protein to produce practically as rapid gains on the same amount of feed per 100 pounds of gain as when it was self-fed.

Since expeller soybean oil meal is too palatable to be self-fed free-choice with corn and minerals, various combinations of feeds with soybean oil meal were mixed and self-fed as supplements to prevent overconsumption of this palatable feed. The results are presented in tables 4 and 5.

Mixing 200 pounds of expeller soybean oil meal with 100 pounds of alfalfa meal to produce a less palatable supplement than soybean oil meal alone for feeding-free-choice on pasture is an economical practice when alfalfa meal is as cheap or cheaper than soybean oil meal. The value of the alfalfa meal is in its ability to prevent overeating on the palatable soybean oil meal. Other chopped legume hays could be used similarly, by adjusting the ratio of soybean oil meal to chopped hay so the pigs will get about ½ pound of soybean oil meal per head daily.

By self-feeding a mixture of 200 pounds ground oats and 100 pounds soybean oil meal in two experiments the average consumption of soybean oil meal was reduced to about 0.4 pound per head daily. This appears to be very satisfactory method of feeding ground oats since it does not necessitate grinding and mixing the complete ration, and, at the same time controls the consumption of soybean oil meal. In Experiments VII and IX, about 16 and 15.6 percent of the average daily feed consisted of ground oats, respectively. An average of the two tests shows that one ton of gound oats so fed was worth slightly more than a ton of the other feeds in producing 100 pounds of gain. In experiment VII (table 4) the pigs fed the ground oats and soybean oil meal mixture gained very significantly faster than pigs fed the mixture of alfalfa meal and soybean oil meal on bromegrass pasture. In Experiment IX (table 5) there was no statistically significant effect on rate or efficiency of gains made by pigs fed either the mixture of 100 pounds

TABLE 4. METHODS OF FEEDING EXPELLER SOYBEAN OIL MEAL SINGLY OR IN MIXTURES WHICH CAN BE SELF-FED

Items compared	Exp. VI began May 31, 1945				Exp. VII began May 31, 1946				Exp. VIII began May 28, 1948		
	1	2	3	4	1	2	3	4	1	2	3
(All supplements were self-fed, free-choice except in Lots 1 and 3 of Exp. VI)											
Supplement fed:											
Soybean oil meal[1]	Hand-fed daily	100	Hand-fed daily	200	200	200	200	100[2]	100	100	
Alf. meal, sun-cured				100		100	100				
Ground Oats								200			
Meat and bone scraps (MBS) or Tankage (T)					100T				100MBS		100MBS
Dried corn dist. sol.[3]										100	100
Pasture used	Alfalfa		Bromegrass		Alfalfa		Bromegrass		Bromegrass-Alfalfa		
(All lots self-fed shelled yellow corn and minerals free choice)											
No. of pigs	14	15	14	16	16	16	16[2]	16[2]	25	25[4]	25
Days on test	109	109	116	116	113	122	129	108	110.6	118.8	119.0
Av. initial wt., lb.	52.9	51.0	53.1	50.5	49.6	49.2	49.2	48.8	40.5	40.4	40.7
Av. final wt., lb.	202.2	206.5	199.1	200.9	200.5	199.5	200.8	201.5	197.5	206.0	203.5
Av. daily gain, lb. (wt'd.)	1.37	1.43	1.26	1.30	1.34*	1.23	1.18	1.41**	1.43	1.41	1.38
Av. daily feed:											
Shelled yellow corn, lb.	4.36	4.09	4.22	4.11	4.30	4.20	3.90	4.05	4.35	4.08	4.21
Supplement, lb.	.48	.91	.48	.63	.34	.36	.69	1.31	.43	.58	.30
Minerals, lb.	.04	.04	.04	.03	.06	.06	.06	.06	.005	.017	.009
Total, lb.	4.88	5.04	4.74	4.77	4.70	4.62	4.65	5.42	4.78	4.68	4.52
Feed per 100 lb. gain:											
Shelled yellow corn, lb.	318.0	286.7	335.1	317.1	322.2	341.3	331.8	287.7	301.9	288.2	303.0
Supplement, lb.	34.7	63.5	38.3	49.4	25.8	29.6	59.0	93.0	30.0	41.1	21.4
Minerals, lb.	2.6	2.7	2.8	2.4	4.2	4.7	5.4	4.5	0.3	1.2	0.6
Total, lb.	355.3	352.9	376.2	368.9	353.2	375.6	396.2	385.2	332.2	330.6	325.0
Crude protein content of supplement, %	—	—	—	—	52.2	35.5	35.5	22.8	49.8	36.3	39.2

[1] Expeller soybean oil meal, 42% crude protein. [2] One pig removed.

[3] For the first 2 weeks the ratio was 100 soybean oil meal and 100 ground oats. [4] One pig died after 34 days on test.

[5] The dried corn distillers' solubles contained 3.7% moisture, 26.6% protein, 3.2% fat, 2.3% fiber and 12.3% ash. The mash bill was 60% corn, 15% milo, 15% rye and 10% barley malt.

* $P \leq 0.05$, significant over Lot 3. ** $P \leq 0.01$, highly significant over Lots 2 and 3. No statistically significant differences between daily gains of lots in Exps. VI and VIII.

TABLE 5. METHODS OF FEEDING SOLVENT SOYBEAN OIL MEAL IN MIXTURES THAT CAN BE SELF-FED WITH COMPARISON OF NIGHT LIGHTS VERSUS NO NIGHT LIGHTS

(Experiment IX began May 2, 1949)

Items compared	1	2	3	4	5
Supplement fed:					
Solvent soybean oil meal	100	100	100	100	100
Meat and bone scraps	100	100	—	100	100
Ground oats	—	—	200	—	—
Dried corn dist. solubles	—	—	—	100	—
Night lights	—	—	—	—	+
Pasture used	Bromegrass-alfalfa	Alfalfa	Alfalfa	Bromegrass-alfalfa	Bromegrass-alfalfa
(All lots self-fed shelled yellow corn, minerals and supplements, free-choice)					
No. of pigs	20	20	20	20[1]	20[2]
Days on test	112	113	123	118	113
Av. initial wt., lb.	36.2	36.3	36.3	35.6	36.4
Av. final wt., lb.	201.4	202.8	207.0	198.2	202.9
Av. daily gain, lb. (wt'd)	1.47	1.48	1.40	1.38[1]	1.47
Av. daily feed:					
Shelled yellow corn, lb.	4.59	4.57	3.70	4.14	4.26
Supplement, lb.	0.53	0.52	1.10	0.58	0.79
Minerals, lb.	0.003	0.003	0.048	0.005	0.004
Total, lb.	5.12	5.10	4.85	4.72	5.05
Feed per 100 lb. gain:					
Shelled yellow corn, lb.	312.4	309.2	265.9	301.0	287.7
Supplement, lb.	36.0	35.3	78.7	42.1	53.3
Minerals, lb.	0.2	0.2	3.4	0.3	0.2
Total, lb.	348.6	344.7	348.0	343.4[1]	341.2
Electricity required, kilowatt hours	—	—	—	—	68
Crude protein content of supplements, %	49.5	49.5	22.7	40.6	49.5

[1] On August 1, 8 pigs were sold from this lot. The average daily gain is for 12 pigs that remained in the lot during the entire test. The feed per 100 lb. of gain is based upon the total feed consumption and gains of the 20 pigs.

[2] Only 17 pigs finished, since two pigs died and one unthrifty pig was removed.

meat and bone scraps plus 100 pounds soybean oil meal or the mixture of 200 pounds ground oats and 100 pounds soybean oil meal.

Considering the data in the experiments summarized in tables 4 and 5, the rates of gain between groups of pigs did not differ significantly when the following supplemental mixtures were self-fed free choice with shelled yellow corn and minerals on similar pastures: (a) 100 tankage (60% crude protein) plus 100 expeller soybean oil meal; (b) 200 expeller soybean oil meal

plus 100 alfalfa meal; (c) 100 expeller soybean-oil meal plus 200 ground oats; (d) 100 meat and bone scraps (50% crude protein) plus 100 of either expeller or solvent soybean oil meal; (e) 100 meat and bone scraps plus 100 dried corn distillers' solubles; (f) 100 expeller soybean oil meal plus 100 dried corn distillers' solubles; and (g) equal parts by weight of meat and bone scraps, dried corn distillers' solubles and solvent soybean oil meal.

All supplements were of good texture and fed down freely in the self-feeders except the one composed of 100 meat and bone scraps plus 100 dried corn distillers' solubles, which tended to be sticky and to pack in the self-feeder. From the results of Experiment VIII it appears that dried corn distillers' solubles can replace meat and bone scraps somewhat more advantageously than it can replace expeller soybean oil meal in the supplemental mixture. Dried corn distillers' solubles can be used satisfactorily as 50 percent of the pasture supplement without appreciably affecting either rate or efficiency of gains.

E. Solvent versus Expeller Soybean Oil Meal for Growing-Fattening Pigs on Alfalfa Pasture

Solvent soybean oil meal was somewhat more palatable and was consumed in greater amounts daily than expeller soybean oil meal when each was self-fed free-choice to pigs with shelled corn and minerals on alfalfa pasture (table 6). For the first 78 days on test the average daily consumption of soybean oil meal per pig was 0.75 pound and 0.99 pound for those receiving expeller or solvent soybean oil meal, respectively. During the same period, the pigs receiving solvent soybean oil meal gained 1.19 pounds per head daily which was very significant more rapidly than the 1.07 pounds average daily gain of those receiving expeller soybean oil meal ($P \leqq 0.01$). For the entire test the pigs receiving solvent soybean oil meal made more rapid daily gains than those fed expeller soybean meal, but the difference of 0.10 pound in average daily gain was not statistically significant (odds 17:1).

F. Meal versus Pelleted Supplement

Pigs fed pellets ($\frac{3}{8}$ inch diameter and $\frac{1}{4}$ to $\frac{3}{8}$ inch in length) consumed 8.4 pounds more supplement and 17 pounds less shelled corn per 100 pounds of gain than pigs fed meal supplement (Experiment XII, table 6), with no significant difference in rate of gain of the two groups.

G. Night Lights of No Value in Pasture Test

Exposing self-fed pigs on bromegrass-alfalfa pasture to night lights (2–150 watt reflector bulbs) for two intervals of one hour each (10–11 p. m. and 3–4 a.m., CDT) had no significant effect on average daily gains, daily

TABLE 6. SOLVENT VERSUS EXPELLER SOYBEAN OIL MEAL AND MEAL VERSUS PELLETED SUPPLEMENT FOR GROWING-PIGS SELF-FED THESE SUPPLEMENTS FREE-CHOICE WITH SHELLED YELLOW CORN AND MINERALS ON ALFALFA PASTURE

Items compared	Experiment XI began June 13, 1949		Experiment XII began May 18, 1949	
Supplement	Expeller	Solvent	Meal supp.	Pelleted[1] supp.
	soybean oil meal	soybean oil meal	100 expeller soybean oil meal 100 meat and bone scraps	100 expeller soybean oil meal 100 meat and bone scraps
Number of pigs	24[2]	24[3]	25	25
Av. initial weight, lb.	46.8	45.2	40.9	40.9
Av. final weight, lb.	200.3	201.4	200.0	198.8
Av. daily gain, lb. (weighted)	1.27	1.37	1.45	1.44
Av. daily feed:				
Shelled yellow corn, lb.	3.64	3.98	4.48	4.21
Supplement, lb.	0.77	0.89	.35	.47
Minerals, lb.	0.03	0.03	.006	.005
Total, lb.	4.44	4.90	4.836	4.685
Feed eaten per 100 lb. gain:				
Shelled yellow corn, lb.	296.1	290.2	308.0	291.1
Supplement, lb.	62.9	64.9	24.0	32.4
Minerals, lb.	2.5	1.9	0.4	0.4
Total, lb.	361.5	357.0	332.4	323.9
Crude protein content of supplements, %	43.38	48.00	49.75	48.06
Dry matter content of supplements, %	87.82	87.71	92.13	91.55
Fat content of supplements, %	5.50	0.61	—	—

[1] Acknowledgment is made to the Illinois Farm Supply Company, Chicago, Illinois, for pelleting the supplement.
[2] Seven pigs removed and their daily gains were not used in computing average daily gain for lot.
[3] One pig removed.

feed consumption or the feed required per 100 pounds of gain (Lot 1 versus Lot 5, table 5).

Summary and Conclusions

1. Growing-fattening pigs self-fed to 200 pounds required 5.5% more concentrates per 100 pounds of gain on bromegrass than on alfalfa pasture. The pigs on alfalfa pasture consumed 33% less protein supplement and 13% less minerals per unit of gain and reached the final weight one week earlier.

2. Bromegrass-alfalfa pasture was fully equal to alfalfa pasture for self-fed pigs.

3. In comparisons within experiments on similar pastures, the rates of gain between groups of pigs differed slightly but not significantly when the following supplemental mixtures were self-fed free-choice with shelled yellow corn and minerals (parts by weight): (a) 100 tankage (60% crude protein) plus 100 expeller soybean oil meal; (b) 200 expeller soybean oil meal plus 100 alfalfa meal; (c) 100 expeller soybean oil meal plus 200 ground oats; (d) 100 meat and bone scraps plus 100 of either expeller or solvent soybean oil meal; (e) 100 meat and bone scraps plus 100 dried corn distillers' solubles; (f) 100 expeller soybean oil meal plus 100 dried corn distillers solubles; and (g) equal parts of meat and bone scraps, dried corn distillers' solubles and solvent soybean oil meal.

4. When expeller soybean oil meal was self-fed feee-choice the pigs ate almost twice as much as those hand-fed only enough ($\frac{1}{2}$ pound per pig daily) to balance the protein content of the ration without significantly increasing either the rate or the efficiency of gain.

5. Solvent soybean oil meal was more palatable and was consumed in larger quantity than expeller soybean oil meal when each was self-fed free-choice to pigs receiving shelled yellow-corn and minerals.

6. Pigs self-fed pelleted supplement free-choice on pasture ate 8.4 pounds more supplement and 17 pounds less shelled corn per 100 pounds of gain than pigs fed the same supplement as a meal.

7. Exposing self-fed pigs on bromegrass-pasture to night lights (2-150 watt reflector bulbs) for two intervals of one hour each (10–11 P.M. and 3–4 A.M.) had no significant effect on performance in comparison to controls fed the same ration without exposure to the night lights.

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SODIUM, CHLORINE, AND POTASSIUM REQUIREMENTS OF GROWING PIGS[1]

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SODIUM, chlorine, and potassium are essential elements. The essentiality of salt for growing and fattening swine has been demonstrated in experiments by Evvard *et al.* (1925), Sinclair (1926), Kirk and Crown (1942) Vestal (1947), and Grummer *et al.* (1949). The minimum requirements of sodium and chlorine for optimum growth of swine, however, were not determined in these experiments. Hughes and Ittner (1942) showed that the growing pig required about 2.36 grams of potassium per 100 pounds of live weight daily for optimum growth.

The experiments reported herein were conducted to determine the minimum sodium, chlorine, and potassium requirements for optimum growth of swine. These investigations were considered desirable because of the lack of data on the sodium and chlorine needs of swine. The potassium requirement was also reinvestigated since the methods used allowed this information to be easily obtained.

Experimental

A basal ration low in sodium chloride (table 1) was used in these experiments. Sodium and chlorine were added as the bicarbonate and ammonium salts respectively. The ration was supplied *ad libitum*. Water, which contained an insignificant amount of sodium, chlorine, and potassium, was given twice daily.

Thrifty, uniform, weanling Hampshire pigs were used in this study. Four pigs were assigned to each lot and each lot was housed in a metabolism cage.

The design of experiments I and II is shown in table 2. Experiment 1 was a preliminary trial in which rations low in sodium chloride, chlorine, and sodium were fed to observe the effects of possible deficienceis. An indication of the retention of sodium and chlorine was obtained from a short balance study of the pigs in these lots. Blood plasma analyses for sodium, chloride, and potassium were made at the termination of the experiment.

Experiment II was designed to determine the sodium requirement as

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TABLE 1. SODIUM CHLORIDE-LOW BASAL RATION[1,2]

	%	Salts	
Sucrose	71.8		%
Casein (alcohol ext.)	18.0	K_2HPO_4	21.35
Corn oil	5.0	$CaHPO_4$	34.45
Salts	5.2	$CaCO_3$	22.55
	mg./kilo ration	$MgSO_4 \cdot 7H_2O$	17.90
		Fe citrate $\cdot 6H_2O$	3.17
Thiamin	2	$Mn_4 \cdot 1H_2O$	0.27
Riboflavin	3	KI	0.11
Pyridoxine	4	$ZnSO_4$	0.05
Niacin	10	$CuSO_4$	0.05
Ca Pantothenate	20		
Choline	1000		
B_{12} Concentrate	1000		

[1] 0.005 percent sodium, 0.03 percent chlorine, and 0.50 percent potassium by analyses.
[2] 10 cc. of cod liver oil supplied each pig weekly.

indicated by growth data and to determine the sodium, chlorine, and potassium requirements by balance studies. Lot 1 was given a ration containing 0.03 percent sodium because feeding trials (unpublished data) with natural rations containing this amount of sodium did not produce a sodium deficiency. Lot 3 was given 0.09 percent sodium which was based on the amount of sodium retained in the balance study of the control lot of experiment I. Blood plasma analyses were also made at the end of the experiment.

The balance study consisted of 3 consecutive periods of 7 days each and was not begun until the pigs had been on the experimental ration 1 week, thus allowing the digestive tract to be cleared of the pre-experimental ration. During each period the pooled urine and feces of each lot were periodically collected, measured or weighed, and aliquots taken for analysis. Any feed wasted was weighed back. At the end of each 7-day period the cages were washed and the washings collected for analysis.

TABLE 2. PERCENTAGES OF SODIUM AND CHLORINE IN THE RATIONS OF THE EXPERIMENTAL LOTS

Experiment I			Experiment II		
Lot No.	Sodium	Chlorine	Lot No.	Sodium	Chlorine
	%	%		%	%
1	0.005	0.03	1	0.03	0.33
2	0.205	0.03	2	0.06	0.33
3	0.005	0.33	3	0.09	0.33
4	0.205	0.33	4	0.20	0.33

The sodium and potassium analyses were made with the Perkin-Elmer model 52-A flame photometer. The chloride content of the ration and feces was determined by the method of Fraps and Brown (1947). Blood plasma and urine chlorides were determined by the method of Whitehorn (1921) and Harvey (1910) respectively. The analysis of variance as given by Snedecor (1946) was used for the statistical treatment of growth data and blood plasma analyses. Least significant difference was used to detect differences between the treated lots and the controls.

Results and Discussion

Experiment I

The growth and feed consumption results of experiment I are shown in table 3. The average daily gains of the sodium chloride and sodium-deficient lots were 0.49 and 0.48 pound respectively. The controls gained 1.15 pounds per day, which was a highly significant difference in daily weight gain from the above lots. A significantly lower gain resulted from the chlorine deficiency of lot 2. The data on the feed required per pound of gain demonstrated essentially the same differences. It was interesting to note that pigs' growth retardation from the sodium chloride-deficient ration

TABLE 3. GROWTH AND FEED CONSUMPTION RESULTS

Experiment I

Items compared	Lot 1 Low NaCl	Lot 2 Low Cl	Lot 3 Low Na	Lot 4 Control
Pigs per lot	4	4	4	4
Experimental period, weeks	6	6	6	6
Av. initial wt., lb.	31.0	31.5	32.0	31.0
Av. final wt., lb.	51.5	67.3	52.5	79.8
Av. da. gain, lb.	0.49**	0.85**	0.48**	1.15
Av. da. feed consumed, lb.	2.00	2.34	2.05	2.23
Feed consumed per lb. gain, lb.	4.11	2.74	4.13	1.93

Experiment II

Items compared	Lot 1 Na 0.03%	Lot 2 Na 0.06%	Lot 3 Na 0.09%	Lot 4 Na 0.20%
Pigs per lot	4	4	4	4
Experimental period, weeks	4	4	4	4
Av. initial wt., lb.	38	38	38	36
Av. final wt., lb.	65	67	77	74
Av. da. gain, lb.	0.96**	1.11*	1.38	1.35
Av. da. feed consumed, lb.	2.38	2.49	2.54	2.73
Feed consumed per lb. gain, lb.	2.54	2.40	1.99	2.04

** Highly significant or *significant difference from lot 4.

was no greater than that from the low sodium ration. With the exception of poor growth, the only symptom noted in the above deficiencies was the great avidity of the pigs for licking all parts of the cages for salt.

Table 4 summarizes the data on the sodium, chloride, and potassium content of the blood plasma. Although there was a decrease in the sodium concentration in the blood plasma of the sodium chloride, chlorine, and

TABLE 4. BLOOD PLASMA SODIUM, CHLORIDE, AND POTASSIUM

Experiment I

Items compared	Lot 1 Low NaCl	Lot 2 Low Cl	Lot 3 Low Na	Lot 4 Control
	mg./100 cc.	mg./100 cc.	mg./100 cc.	mg./100 cc.
Sodium	284	289	287	303
Chlorine	279**	244**	299*	346
Potassium	30*	22	30*	23

** Highly significant or * significant difference from lot 4.

Experiment II

Items compared	Lot 1 Na 0.03%	Lot 2 Na 0.06%	Lot 3 Na 0.09%	Lot 4 Na 0.20%
	mg./100 cc.	mg./100 cc.	mg./100 cc.	mg./100 cc.
Sodium	308	339	329	328
Chlorine	292	304	312	303
Potassium	26	26	26	23

sodium-deficient pigs, the individual variation was so great that the differences were not statistically significant. However, there was a significant or highly significant decrease in the chloride content of the blood plasma of the pigs in all three deficiencies. Potassium rose to a significant degree in the blood plasma of the sodium chloride and sodium-deficient pigs.

Experiment II

The growth and feed consumption results are shown in table 3. The average daily gains indicate that the sodium requirement for optimal growth of the pigs was found to be between 0.06 and 0.09 percent of the ration. The weight gains of lot 2 were significantly lower while those of lot 3 were equal to those of the control pigs. The efficiency of feed utilization followed a pattern similar to that of the growth data.

Analyses of the blood plasma, presented in table 4, did not show significant differences in the sodium, chloride, and potassium concentration. There was, however, a tendency for the pigs receiving 0.03 percent sodium

in the ration to have a reduced concentration of blood plasma sodium and chloride.

The data from the balance studies are presented in table 5. The pigs fed the rations containing 0.03 and 0.06 percent sodium retained daily 11.46 and 24.47 milligrams of sodium per kilogram live weight while lots 3 and 4, receiving 0.09 and 0.20 percent sodium in the ration, retained respectively 33.07 and 35.27 milligrams of sodium per kilogram of body weight daily.

TABLE 5. BALANCE STUDIES OF EXPERIMENT II

Items compared	Lot 1 Na 0.03%	Lot 2 Na 0.06%	Lot 3 Na 0.09%	Lot 4 Na 0.20%
Sodium Balance Study				
Grams per pig per week:				
Intake	2.28	4.82	7.58	16.98
Excreted, urine and feces	0.34	0.53	1.51	10.63
Retained	1.94	4.29	6.07	6.35
Percentage retained	85.09	89.00	80.08	37.40
Retained per kilo body wt. per day, milligrams	11.46	24.47	33.07	35.27
Chlorine Balance Study				
Grams per pig per week:				
Intake	21.94	23.16	24.04	25.58
Excreted, urine and feces	15.42	14.72	15.44	15.86
Retained	6.52	8.44	8.60	9.72
Percentage retained	29.71	36.51	35.77	37.00
Retained per kilo body wt. per day, milligrams	39.24	49.16	46.95	56.22
Potassium Balance Study				
Grams per pig per week:				
Intake	40.14	42.05	43.68	46.45
Excreted, urine and feces	22.86	20.62	26.03	24.56
Retained	17.28	21.43	17.65	21.89
Percentage retained	43.05	50.97	40.41	47.13
Retained per kilo body wt. per day, milligrams	100.97	121.03	93.69	111.33

The chlorine balance of the swine receiving 0.06, 0.09, and 0.20 percent sodium in the ration was approximately the same, ranging from 46 to 56 milligrams of chlorine daily per kilogram of live weight. Lot 1 pigs did not retain as much chlorine as the fore-mentioned lots.

The potassium retention of all the lots appeared to be the same, varying from 93 to 121.03 milligrams per kilogram body weight daily. Differences in retention levels did not seem to be correlated with the amount of sodium in the ration.

The path of greatest excretion of sodium, chlorine, and potassium of the

control pigs, lot 4, was the urine where 97 to 98 percent of the elements were recovered. The chlorine and potassium excretion of the other 3 lots was similar to the control pigs. When the sodium was decreased in the ration, as in lots 1, 2, and 3, the proportion of sodium excreted in the urine decreased. Despite this fact, 72 to 89 percent of the sodium was excreted in the urine of the pigs on the low sodium rations. The low percentage of these elements that appeared in the feces was in part due to the very small amount of feces excreted. This amounted to an average of 3.2 pounds per pig per week. It was also noted that when the pigs were receiving a suboptimum amount of sodium that the sodium retention was only 85 to 89 percent of the intake.

Discussion

The growth data indicate that swine fed a purified ration require 0.09 percent sodium for optimum growth. The balance study substantiated this because the pigs on 0.09 percent sodium retained about the same amount of sodium as the controls. It appears that pigs cannot retain 100 percent of the sodium intake, since the pigs on the suboptimum levels of sodium retained only 85 to 89 percent of the intake. Therefore, in order to calculate the sodium requirement from the sodium balance, 11 to 15 percent must be added to that actually retained by the pigs making optimum growth. When this is done each pig should receive for optimum growth approximately 36 to 42 milligrams of Na per kilogram live weight daily. Expressed as percentage of feed consumed, this amounts to 0.08 to 0.10 percent.

The chlorine retention of the pigs making the best growth amounted to 46.95 to 56.64 milligrams per kilogram body weight per day. It also appears that pigs will not retain 100 percent of the chlorine intake when on a minimum level. The short balance study in experiment I indicated that the pigs retained only 88 percent of the chlorine intake when fed a chlorine-low ration. Using this figure, a ration should contain enough chlorine to supply 53 to 64 milligrams of the element daily per kilogram of weight. A level of 0.12 to 0.13 percent of this ration would satisfy this requirement.

Pigs making optimum growth retained 93.69 to 111.33 milligrams of potassium per day per kilogram live weight. Figures are not available as to the maximum amount of potassium that would be retained if the pigs are on a minimum level. It is suggested that the ration supply 100–120 milligrams of potassium per kilogram body weight per day. This amounts to 0.23 to 0.28 percent of the ration.

The average daily potassium requirement found in these experiments was 5.15 grams per 100 pounds of live weight. This figure is about double that obtained by Hughes and Ittner (1942) which was 2.36 grams. One explanation for the divergent results may be the differences in rate of gain.

As far as can be ascertained from their data the pigs in their experiment gained at one half the rate of the pigs in our experiments. A decrease in daily gains should cause a decreased requirement.

An interesting point to note is that the ratio of sodium to chlorine retained in the groups making optimum growth was 1 to 1.42 and 1 to 1.53. The ratio of sodium to chloride in salt is 1 to 1.54. This suggests that salt supplies sodium and chlorine in about the proper proportions for growing pigs.

Summary

Sodium, chlorine, and sodium chloride deficiencies were produced in pigs with a resultant decrease in daily gains and in efficiency of feed utilization. The sodium chloride deficiency was no more severe than the sodium deficiency alone.

Blood plasma studies of the concentration of sodium indicate that blood plasma sodium cannot be used positively to detect a sodium deficiency. The chlorine deficiency caused a significant decrease of the blood plasma chlorides. Coincident with the severe sodium deficiency was a significant rise of potassium in the blood plasma.

The growth data for the sodium and the balance studies for sodium, chlorine, and potassium suggest that the requirements for growing swine making average daily gains of approximately 1.35 pounds are 36 to 42 milligrams of sodium, 53 to 64 milligrams of chlorine, and 100 to 120 milligrams of potassium per kilogram body weight daily.

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THE RELATION OF THE POST-PARTUM BREEDING INTERVAL TO REPRODUCTIVE EFFICIENCY IN THE DAIRY COW

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FOR profitable milk production the dairy cow must reproduce regularly. An interval of 12 to 13 months between calves usually is considered satisfactory. Cows calving every 12 months or less had higher yields per day for the interval between calves than did cows that required more than 12 months before reproducing in studies by Gaines and Palfrey (1931) and Chapman and Casida (1935). This observation suggests that optimum milk-producing efficiency would be obtained by breeding cows as soon as possible after calving. Such a practice fails to consider the other possible physiological aspects of the problem.

Casida and Venzke (1936) found that approximately 26 days were required following calving for the uterus to return to normal position, tonus, and size. Hofstad (1941) in a study of 309 conceptions in a dairy herd in New York reported that 34 cows bred before the sixtieth day following calving required a higher average number of services per conception than did cows first bred more than 60 days after calving. The percentage of abortions and cases of metritis, dystocia, and retained placenta were much higher in the animals bred at less than 60 days post-partum than in those first bred later than that date. In a study of 291 range cattle, Lasley and Bogart (1943) found that of 35 cows bred 10 to 40 days after calving 48.6 percent settled with one insemination, but a maximum fertility of 75 percent conception with one insemination was obtained in 12 cows bred 161 to 190 days after calving. Erb and Shaw (1948) reported in a summary of a survey of breeding failures in Washington that there was an apparent improvement in breeding efficiency by waiting at least 50 days after calving before rebreeding. Similar improved results for delayed breeding have been reported by Jennings (1941) in breeding mares less than 9 days following foaling as compared with allowing more rest after foaling before rebreeding.

While the literature indicates that lowered reproductive efficiency may result from breeding too soon after calving, the evidence is limited. Records in one of the artificial breeding units in Illinois show that 20 to 25 percent of the cows are being serviced in a post-partum breeding interval of less than 60 days. This practice and the limited evidence available concerning

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what recommendations should be made prompted a detailed study of the breeding records of the cows in the University of Illinois dairy herd to determine the effect of the post-partum breeding interval on reproductive efficiency.

Methods

The breeding records of 593 cows representing the five major dairy breeds in the University of Illinois dairy herd were analyzed to determine the post-partum interval to first service for each conception which occurred over a period of approximately 28 years. The conceptions in this study were predominately from natural service.

Data on a total of 1,674 pregnancies, as confirmed by subsequent calving, were tabulated to show the number of days post-partum when first service was accomplished and the number of services required for conception in each case. Pregnancies which terminated in abortion were omitted since in such cases, where more than one service was required, the service date at which conception took place could not be definitely fixed.

The simple correlation coefficient between the post-partum interval to first service and the number of services required for conception was calculated on the individual observations. Methods described by Snedecor (1946) were used also to test the goodness of fit of the data to a second degree polynomial curvilinear regression using the formula $Y=a+bX+cX^2$, where Y represents the estimated number of services per conception, and X is the number of days from calving to the first subsequent service.

Results and Discussion

In this study of 1,674 pregnancies in 593 cows it was found that 1.97

TABLE 1. THE NUMBER AND THE PERCENT OF THE TOTAL NUMBER OF COWS CONCEIVING AT EACH OF A SERIES OF CONSECUTIVE SERVICES

Services required per conception	1	2	3	4	5	6	7	8	9	or more
Number mated	1674	740	388	202	116	68	39	24	15	
Number of conceptions	934	352	186	86	48	29	15	9	15	
Percent conceptions	55.8	47.6	47.9	42.6	41.4	42.6	38.5	37.5	100	
Percent of total conceptions	55.8	21.0	11.1	5.1	2.9	1.7	0.9	0.5	0.9	

services were required per conception over the entire period of 28 years. In table 1 a breakdown of the total conceptions shows that 55.8, 21.0, 11.1, and 5.1 percent of the conceptions were accomplished on the first, second, third, and fourth services, respectively; the remaining 7 percent of the pregnancies took 5 or more services with nearly 1 percent of these requiring 9 or more services. These results show a conception rate only slightly altered

from that presented by Trimberger and Davis (1945) for artificial breeding. Also, the results show the usual decrease in the efficiency of each subsequent service as the more highly fertile cows at a particular service are selected out by becoming pregnant. The breeding efficiency for each of the first 5 services was as follows: 55.8 percent conception in first service cows, 47.6 in second, 48.0 in third, 42.6 in fourth, and 41.4 percent conceptions in cows serviced for the fifth time.

The effect of the length of the post-partum interval to first service on reproductive efficiency is indicated in table 2. From this table it can be seen

TABLE 2. EFFECT OF THE TIME INTERVAL TO FIRST BREEDING AFTER CALVING ON THE SERVICES REQUIRED FOR CONCEPTION IN THE UNIVERSITY OF ILLINOIS DAIRY HERD

Post-partum interval to 1st service (days)	Total number conceptions	Total number services	Services per conception	Percent services resulting in conceptions
1– 20	7	20	2.86	35.0
21– 40	75	183	2.44	41.0
41– 60	130	295	2.27	44.0
61– 80	242	476	1.97	50.8
81–100	269	505	1.88	53.2
101–120	218	377	1.73	57.8
121–140	241	460	1.91	52.4
141–160	191	366	1.92	52.1
161–180	106	208	1.96	51.0
181–200	80	155	1.94	51.6
201 and over	115	248	2.16	46.3
Totals	1674	3293		
Means 117 (days)			1.97	50.8

that on the average the cows first bred within 20 days after calving required 2.86 services per conception, thus, only 35.0 percent of the services resulted in conception. The average fertility level of the cows increased with each additional 20 day interval, with a maximum number of services resulting in conception in those cows first bred 101 to 120 days after calving. This group required 1.73 services per conception. With a post-partum interval to first service of 121 to 200 days there was little change in reproductive efficiency. The percentage of services resulting in conception was slightly lower in cows first bred more than 200 days after calving.

Calculation of the simple correlation coefficient between the post-partum interval to first service (days) and the number of services required for conception for each calf produced resulted in an r value of $-.02$, which is not significant. However, analyses of only the 454 conceptions which

occurred from breeding within 80 days after parturition showed a significant correlation coefficient of −.116 between the days postpartum to first service and the services required for conception. The simple regression line of that analysis is presented in figure 1 as the solid line.

Since the over-all picture showed no simple correlation between time of breeding after calving and reproductive efficiency, but did show a significant

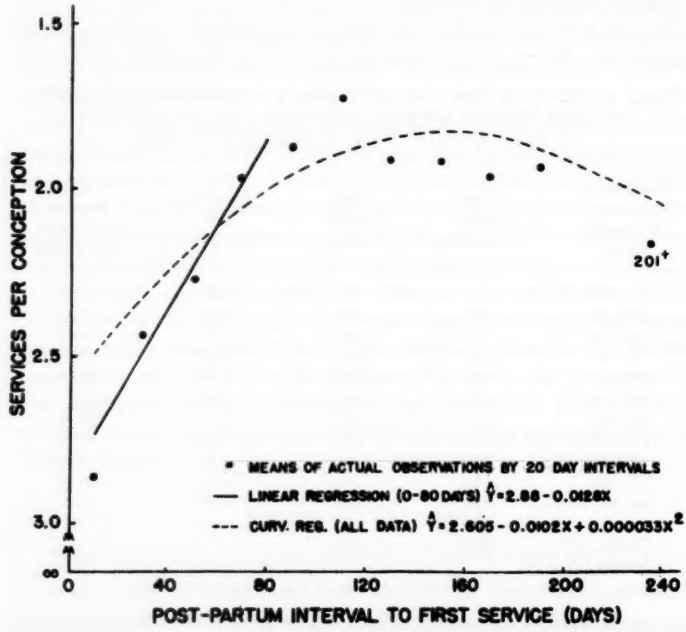

Figure 1. Actual means by 20 day intervals, and calculated linear (data for 0–80 days post-partum) and curvilinear regression (all data) of services per conception on post-partum interval to first service (days) in the University of Illinois dairy herd.

relationship between these two for one portion of the data, the possibility of a curvilinear relationship was suggested.

When the entire body of data was fitted to a curve by the use of the second degree polynomial regression equation, $Y=a+bX+cX^2$, it was found that the departure from linear regression or the curvilinearity of the data was highly significant. The regression equation derived from the data was $Y=2.605-0.0102X+0.000033X^2$, where X is the number of days from parturition to first service and Y is the resulting estimated number of

services required for conception. The analysis resulted in a multiple correlation coefficient of $R = 0.10$, which is significant at the 1 percent level of probability. Though significant, this multiple correlation coefficient shows that only a very small portion of the variance in services required for conception was accounted for by the interval after calving when a cow was first bred.

The regression curve describing the data is illustrated in figure 1 by the broken line. The actual averages of the data for each time interval shown in table 2 also are indicated in figure 1. An analysis of variance showed the differences between the mean number of services required for conception at the various time intervals were significant at the 1 percent level of probability.

Discussion

The results of this study with known fertile cows indicate that reproductive efficiency in dairy cows increases as the post-partum interval to first breeding increases up to a limit. In these studies maximum breeding efficiency resulted when breeding was delayed an interval of from 100 to 120 days after calving and decreased slightly thereafter. The mean post-partum interval to first service was 117 days and the standard deviation was 53.3 days. This long interval probably was not due to pathological conditions making postponement of service advisable on that account, but to the fact that most of these cattle were routinely milked for 365-day lactation periods. Gaines (1927) in his studies of Guernsey cows on Advanced Registry tests found the average post-partum interval to conception to be 174 days whereas in this case it was approximately 158 days. From the results of this and other studies, it is questionable if a standard interval from calving to first service can be recommended for optimum results under all conditions. However, it seems well established that a certain minimum post-partum interval is required for involution of the uterus (Casida and Venzke, 1936) for the cow to come into estrus following calving (Chapman and Casida 1934), and for recovery of the uterine mucosa so as to avoid possible infections consequent to service (Hofstad, 1941). On the other hand, these minima probably vary within fairly wide limits and may be dependent to some degree on a relation to the mammary gland. Cows milked 2× daily came into heat following calving on the average 23 days sooner than did cows milked 4× daily in data reported by Clapp (1937). Whether or not this effect is a consequence solely of frequency of milking and not of level of production cannot be ascertained, though presumably frequency of milking is of major importance as nurse cows suckling calves showed first estrus after calving somewhat later than did cows milked 4× daily. There is

some evidence suggesting that level of milk yield has no observable effect on reproductive efficiency (Gaines, 1927) as measured by the length of the service period, or the post-partum conception interval.

From the standpoint of milk production itself, the effect of pregnancy in accelerating the rate of decline after the midpoint of the gestation period is well known, and may influence markedly the total production in a lactation. However, Gaines and Palfrey (1931) and Chapman and Casida (1935) have shown that prolongation of the calving interval results in a decrease in the average production per day between calves. On the other hand, the gain in milk yield per day in the current lactation from a short calving interval is lost in the following lactation (Matson, 1929; Gaines and Palfrey, 1931). Matson also concluded that the optimum calving interval varied directly with the milking capacity of the individual cow and inversely with her age up to maturity. Thus, it appears that no date can be fixed as the optimum post-partum breeding interval which would be applicable to all cows in general. However, the lowered conception rate, the probable increased breeding troubles, and the questionable net gain in production over a period of more than one lactation from a short post-partum breeding interval suggest that it is probably unwise to breed cows sooner than 60–80 days after calving.

Summary

A study of 1674 pregnancies in 593 cows of the University of Illinois dairy herd showed that:

(1) A mean of 1.97 services were required per conception, and the mean post-partum interval to first service was 117 days. The standard deviation of services per conception was 1.60 and of post-partum interval was 53.3 days.

(2) Fertility increased with the length of the post-partum interval to first service up to 100 to 120 days.

(3) In the cows bred less than 20 days after calving only 35 percent of the services resulted in conceptions, while nearly 58 percent of the services were effective in those cows bred 100 to 120 days after calving.

(4) Reproductive efficiency for the cows first bred 120 to 200 days after calving remained fairly constant, but those first bred more than 200 days after calving required a slightly greater number of services per conception.

(5) The simple correlation between the post-partum interval to first service and reproductive efficiency was not significant; however, a curvilinear relationship was indicated by the significant departure from linearity when the data were fitted to a curve by the use of a second degree polynomial curvilinear regression equation.

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THE EFFECT OF SULFAQUINOXALINE ADMINISTRATION ON METABOLISM OF VITAMIN A AND CAROTENE AND ON HEMOGLOBIN IN YOUNG DAIRY CALVES[1,2]

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PRELIMINARY studies have shown that sulfaquinoxaline is very effective against bacterial infections and that it is retained by the animal for a longer period of time than some of the other sulfonamides (Weijlard *et al.*, 1944). It has been found effective as a protective agent against upper respiratory infections of poultry (Delaplane, 1945) and has been demonstrated to be of benefit as a prophylactic against cecal coccidioses (Delaplane *et al.*, 1947). It has been shown that sulfaquinoxaline is slowly absorbed from the digestive tract of sheep and that when administered at more than 400 milligrams per kilogram of live-weight it will cause an increase in the prothrombin time (Cameron and McOmie, 1945).

The early life of a calf has been demonstrated to be a critical period with respect to vitamin A nutrition (Braun and Carle, 1943; Guilbert and Hart, 1934; Moore, 1945; Moore and Berry, 1944) and that this substance is important in the development of resistance to disease as well as for proper body growth and development (Klussendorf, 1945; Phillips, 1944, Phillips *et al.*, 1941; Thorp *et al.*, 1942; Wolbach and Howe, 1925). Before the therapeutic value of sulfaquinoxaline for calf diseases can be fully evaluated, it is desirable to know whether or not this drug will have an effect upon the normal physiological functions of vitamin A with respect to proper calf nutrition.

Experimental

An experiment was designed to determine the effects of sulfaquinoxaline administration upon the vitamin A and carotene levels of the blood plasma of young dairy calves. Concurrently the hemoglobin concentrations were determined and analyses were made for bilirubin and for the presence of the abnormal pigments, methemoglobin and sulfhemoglobin. Male Holstein

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calves procured from various Pennsylvania State Institutional herds when they were 5 days of age were used in the study.

The calves were quartered in individual pens, each equipped with a water bowl, hay manger, and feed trough, in an artificially heated and ventilated experimental calf barn. The rations used for all the calves consisted of eight pounds of Holstein herd milk fed twice daily, with U. S. No. 1 timothy hay and the following calf starter available *ad libitum*: yellow corn meal 406.5 lb., wheat bran 300 lb., crushed oats 400 lb., inseed oil meal 140 lb., soybean oil meal 280 lb., dehydrated alfalfa meal 140 lb., cane molasses 100 lb., dried skimmilk 100 lb., dried corn distillers' solubles 100 lb., irradiated yeast (9F) 0.5 lb., dicalcium phosphate 10 lb., ground limestone 10 lb., iodized salt 10 lb., and Vitamin A feeding oil 3 lb. (2,724,000 USP units of Vitamin A per pound). The calves were managed under these controlled conditions until they were 12 days of age at which age the observation period was started.

Two groups of five normal calves each were used with group I being treated with sulfaquinoxaline while group II was carried as untreated controls. Forty milliliters of blood for vitamin A and carotene analysis were drawn from the jugular vein daily, three hours after the morning feeding for ten consecutive days beginning on the day the calves were thirteen days of age.

Sulfaquinoxaline administration was started on the morning of the third day immediately following the regular bleeding. Since no data were available to serve as a guide, the following arbitrary schedule of administering the sulfonamide was observed for all calves regardless of size: ten grams for the first dose, followed by three five-gram administrations at 12 hour intervals. Sulfaquinoxaline blood concentrations, hemoglobin levels and bilirubin concentrations were determined daily beginning 24 hours after the first administration. Tests for methemoglobin and sulfhemoglobin were made on the same blood samples.

The observations were repeated in a second trial beginning when the calves were 28 days of age and continuing for a similar ten day period. At the end of this time the calves were slaughtered and the vitamin A and carotene concentrations of the livers determined.

Blood carotene and vitamin A levels were determined using a combination of methods by Moore (1939) and Kimble (1939) as modified by Knodt (1948). The sulfaquinoxaline determinations were made according to the Bratton-Marshall (1939) method while observing the precautions suggested by Schlenker (1948). The hemoglobin concentrations were determined by means of the method outlined by Evelyn and Mallow (1938) and bilirubin by a method presented by the same authors (1937). After the entire liver

had been ground in a meat grinder and representative samples had been macerated in a Waring Blendor, the carotene and vitamin A concentrations were determined by the methods suggested by the Association of Vitamin

TABLE 1. MEAN BLOOD PLASMA VITAMIN A AND CAROTENE CONCENTRATIONS

Micrograms per 100 Millimeters

Administration	Group I Sulfaquinoxaline		Group II Control	
	Vitamin A	Carotene	Vitamin A	Carotene
		First Trial		
−1	14	20	13	32
0	14	17	13	29
1	13	16	13	25
2	14	16	12	23
3	13	13	12	22
4	13	13	13	20
5	13	13	12	22
6	13	12	12	20
7	13	13	11	21
8	13	14	11	21
$\bar{X}$	13	15	12	24
Change *	−0.7	−4.7	−1.7	−8.0
		Second Trial		
−1	14	7	12	14
0	14	16	10	13
1	14	16	10	13
2	16	15	11	12
3	17	16	11	14
4	16	15	13	14
5	14	16	12	15
6	14	16	12	15
7	14	23	14	19
8	13	19	13	17
$\bar{X}$	15	17	12	15
Change *	−0.3	+6.3	−2.3	+3.7

* Comparison of the −1, 0 and 1 days with the 6, 7 and 8 days of administration.

Chemists (1947). The above methods were colorimetric and in each instance the percent transmission was measured with an Evelyn photoelectric colorimeter (Evelyn, 1936).

Results and Discussion

The mean daily blood plasma vitamin A and carotene levels of both groups of calves are presented in table 1. The concentrations of the vitamin A and carotene of the livers at the time of slaughter following completion of the second trial are reported in table 2. The daily hemoglobin concentra-

TABLE 2. LIVER VITAMIN A AND CAROTENE CONCENTRATIONS
Micrograms per Gram

Calf No.	Vitamin A	Carotene
	Group I Sulfaquinoxaline	
425	15.0	7.2
426	9.0	3.5
427	17.1	3.0
432	8.1	3.7
434	9.6	3.7
X	11.8	4.2
	Group II Control	
422	11.4	4.9
423	10.5	4.0
431	14.1	2.6
433	18.7	1.9
435	30.3	3.1
$\bar{X}$	17.0	3.3

tions are summarized in table 3, and the sulfaquinoxaline blood levels in table 4.

Under the conditions of these experiments, the blood plasma bilirubin did not reach measurable concentrations. In fact, the percent transmission recorded on the galvanometer of the colorimeter ranged between 95 and 100. While determinations were conducted on all blood samples the amounts of this substance are not recorded because of the questionable accuracy of the measurement. It can be stated that bilirubin was present in negligible amounts or in amounts which would not seem to be important in this problem.

In the first trial, when the averages of the first three samples prior to administration are compared to the means of the last three days of the observation period with respect to vitamin A, it would seem that the control group has decreased more markedly in its concentration per 100 milliliters of blood plasma. In a similar comparison for the second trial it would appear

that the control group increased more in its vitamin A content per 100 milliliters of blood plasma. It will be noted, however, that an unexplainable drop was observed during the first three samplings in the case of the control group. Had the same stability of the blood plasma vitamin A level been present in this group at this time as was observed in group I, the difference between the initial and final means would not have been very large.

On examining the carotene levels it was found in the course of the first trial that the blood plasma concentrations decreased in both groups, most markedly in the control group. In this case, however, one individual, No. 435, had an exceedingly high initial concentration, 70.90 micrograms per 100 milliliters of blood plasma, which was followed by a precipitious drop

TABLE 3. MEAN DAILY HEMOGLOBIN CONCENTRATIONS FROM FOURTH DAY OF OBSERVATION TO END OF PERIOD

Grams per 100 Millimeters

Day	Group I Sulfaquinoxaline		Group II Control	
	First trial	Second trial	First trial	Second trial
4	9.5	8.3	9.9	8.8
5	8.5	9.1	9.9	8.7
6	8.9	8.8	10.0	8.7
7	9.1	8.2	9.5	10.6
8	9.0	8.1	9.6	8.5
9	9.4	8.1	9.3	8.2
10	8.8	8.0	9.5	10.3
$\bar{X}$	9.0	8.5	9.8	9.1

to 24.29 micrograms by the end of the period. The values for this one calf apparently influenced the decrease in the control group, and omitting these figures, the group gave a very close comparison with the treated group. During the second trial both groups exhibited a similar degree of increase in the level of blood plasma carotene. However when these data were analyzed by analysis of variance, there was no significant effect of sulfaquinoxaline administration upon blood carotene and vitamin A.

When the storage of vitamin A and carotene in the liver was studied as presented in table 2, there was no statistically significant difference found between the calves which had been treated with sulfaquinoxaline and those which were not. Although the means indicate a difference, it will be noticed that the higher value of the control group is greatly influenced by one individual, No. 435.

Analyses for blood hemoglobin as presented in table 3 reveal no apparent difference between the groups. At no time were there any indications that the abnormal blood pigments methemoglobin and sulfhemoglobin were formed.

The blood concentrations of sulfaquinoxaline reached the highest point on the third day after the first administration and the drug was not excreted as rapidly as it was absorbed. Although the prothrombin time was

TABLE 4. MEAN DAILY SULFAQUINOXALINE BLOOD CONCENTRATIONS FROM FOURTH DAY OF OBSERVATION TO END OF PERIOD

Millimeters per 100 Millimeters

Day	Free	Total
	First Trial	
4	0.86	2.95
5	1.14	4.08
6	1.01	4.18
7	0.70	3.32
8	0.49	1.97
9	0.20	1.27
10	0.11	0.25
	Second Trial	
4	0.91	3.03
5	0.94	3.17
6	0.98	3.26
7	0.47	1.94
8	0.32	0.67
9	0.14	0.29
10	0.11	0.23

not measured, no hemorrhagic tendencies were observed following removal of the bleeding needles following sampling.

Summary

No apparent effects of the oral administration of sulfaquinoxaline were observed upon blood plasma or liver vitamin A and carotene concentrations of Holstein bull calves under the conditions of this trial.

The administration of sulfaquinoxaline did not affect the concentration of blood hemoglobin, methemoglobin or bilirubin of Holstein bull calves under the conditions of this trial.

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THE EFFECTS OF STILBESTROL, TESTOSTERONE, THYROID ALTERATION AND SPAYING ON THE GROWTH AND FATTENING OF BEEF HEIFERS[1]

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PREVIOUS experimental studies have shown that, in general, no advantage accrues from the spaying of heifers that are going into the feedlot (Gramlich, 1925, 1927; Gramlich and Thalman, 1930; Hart, Guilbert and Cole, 1940). Snapp and Bull (1944) found that pregnant heifers take on a higher degree of finish than do open heifers and stated that "the breeding of yearling heifers that are to be fed for about five months is a sound practice." Studies with broilers (Lorenz, 1945; Thayer, Jaap, and Penquite, 1945; Andrews and Bohren, 1947) have demonstrated an increased growth rate and fat deposition as a result of stilbestrol administration. Testosterone has been shown to have a growth stimulating effect (Kenyon, 1938; McCullagh and Rossmiller, 1941). However, the response is dependent upon dosage level (Goldzieher, 1941).

Materials and Methods

Experiment I

Twenty-five grade Hereford heifers weighing approximately 500 lbs. were used in the first experiment. Five animals were spayed prior to the start of the experiment to serve as positive controls. The heifers were allotted on the basis of weight, quality, type and expected performance into five groups and placed on feed February 19, 1947 and were sold July 15, 1947, an experimental period of 140 days.

It was originally intended to full-feed all groups on an identical ration of ground yellow corn, soybean oil meal, mixed clover-timothy hay, corn silage, minerals and plain salt. However, as the experiment progressed, it became apparent that due to spoilage, the silage was not palatable and the ration was changed. Corn- and cob-meal (80:20 ratio and 90:10 toward the end of the experiment) was substituted for the ground corn and the silage was eliminated.

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The heifers were weighed bi-weekly and blood samples were taken weekly from all animals. All animals were observed daily for indications of estrus and any peculiarity in behavior and appearance.

The following treatments were used: I, control; II, spayed (positive control); III, stilbestrol, pellets implanted subcutaneously in region of shoulders, dosage 42 mg., IV, testosterone propionate, intramuscular injection 50 mg. in oil followed by a second injection of 32.5 mg. 56 days later; V, thiouracil, 4 gm. per animal per day, mixed in soybean oil meal.

At the time of slaughter, the ovaries and thyroids were removed, weighed and preserved for further examination. Carcasses were graded according to federal standards. The dressing percentage was calculated on chilled carcass weights.

Blood cholesterol was determined by the method of Pjoan and Walter (1937) as modified for the Evelyn colorimeter. Erythrocyte counts were made by the standard procedure using a hemocytometer counting chamber.

Experiment II

Forty-five Hereford heifer calves of similar age and weight as in Experiment I were used. Nine heifers were spayed to serve as positive controls.

In order to get data on feed consumption suitable for statistical analysis nine heifers were allotted per group as in Experiment I and the group subdivided into three lots of three heifers each.

The heifers were handled and fed in similar manner as in Experiment I on a ration of corn- and cob-meal, soybean oil meal, clover-timothy hay, and iodized salt. Towards the end of the feeding period the ratio of corn to cob was again increased from 80:20 to a 90:10 ratio.

In order to have similar and adequate intakes, calcium carbonate was mixed with the soybean oil meal to provide one ounce per day per animal. According to estimates based on Morrison's tables (1936) the phosphorus content of the feeds in the amounts fed provided an excess of this mineral. Thus, both minerals were fed in excess of requirements as based on the standards set by the National Research Council (1945).

The treatments for each group were: I, control; II, spayed; III, stilbestrol, pellet implantation as previously, dosage 48 mg.; IV, testosterone propionate, 50 mg. pellet implanted subcutaneously and V, thyroprotein, 0.5 gm. per hundred pounds of body weight daily. Adjustments in dosage levels of the latter were made at approximately 100 pounds gaining intervals.

The heifers were placed on feed December 11, 1947 and hormone treatments were delayed 30 days in order to obtain pre-treatment analysis of serum calcium and phosphorus and to note the uniformity of response of the animals when placed on feed. The feeding period lasted 185 days.

Blood samples were taken from one lot in each group each week.

Serum phosphorus was determined by the method of Fiske and Subbarow and serum calcium by the Clarke-Collip modification of the Kramer-Tisdall methods as outlined by Hawk, Oser and Summerson (1947). Blood lipids were estimated according to the method of Allen (1938).

At the time of slaughter the ovaries were removed, weighed and preserved for further study. The carcass weights were recorded, and graded according to federal standards.

The data on gains, feed consumption, serum calcium and phosphorus, and blood lipids were treated statistically by the methods of analysis of variance and the data on blood lipids were studied in relation to rate of gain by the method of analysis of covariance. Gain and feed consumption were studied by the method of correlation. These methods are outlined by Snedecor (1946).

Results and Discussion

Growth Rate

The data summarizing the effects of treatment on growth rate are presented in tables 1 and 2.

TABLE 1. EFFECT OF CERTAIN HORMONE TREATMENTS ON THE GROWTH AND FATTENING OF HEIFERS

Experiment I—1947
Days on Feed—140

Group	I	II	III	IV	V
Treatment	Control	Spayed	Stilbestrol	Testosterone	Thiouracil
Heifers per treatment	5	5	5	5	5
Average initial wt., lb.	506	494	511	512	507
Average final wt., lb.	795	762	836	806	805
Total gain per animal, lb.	289	268*	325*	294	298
Average daily gain, lb.	2.07	1.91	2.32	2.10	2.13
Feed per 100 pounds of gain					
Concentrates, lb.	463	553	442	509	467
Roughage, lb.	312	338	301	316	314
Average daily feed					
Concentrates, lb.	9.57	10.57	10.27	10.69	9.95
Roughage, lb.	6.45	6.46	6.98	6.65	6.67
Carcass data—grade					
Choice	4	4	2	4	3
Good	1	1	2	1	2
Commercial			1		
Dressing percentage	58.5	59.7	59.8	59.8	58.9

* Differences approach significance ($P < 0.05$) from controls.

Implantation of 42 mg. stilbestrol pellets, resulted in increased rate of gain. It was apparent that the animals on this treatment increased in length of leg, length of back and width of back at a greater rate than the spayed or control groups, although no skeletal measurements were made.

In contrast, the spayed heifers grew more slowly and were smaller at the end of each experiment than either the stilbestrol or control group. This is

TABLE 2. EFFECT OF CERTAIN HORMONE TREATMENTS ON THE GROWTH AND FATTENING OF HEIFERS

Experiment II—1948
Days on Feed—185

Group	I	II	III	IV	V
Treatment	Control	Spayed	Stil-bestrol	Testos-terone	Thyro-protein
Heifers per treatment	9	9	9	9	9
Average initial wt., lb.	504	497	506	505	504
Average final wt., lb.	821	782	876	826	798
Total gain per animal, lb.	317	285*	370*	321	294*
Average daily gain, lb.	1.72	1.54	2.00	1.73	1.59
Feed per 100 pounds gain					
Concentrates, lb.	688	728	623	675	746
Roughage, lb.	424	460	369	420	454
Average daily feed					
Concentrates, lb.	11.81	11.20	12.46	11.70	11.88
Roughage, lb.	7.28	7.09	7.38	7.29	7.23
Carcass data—grade					
Choice				1	
Good	7	7	5	5	5
Low good	1	2	4	2	4
Commercial	1			1	
Grade Index	2.5	2.2	2.5	2.3	2.5
Dressing percentage	60.8	59.8	60.6	60.1	60.4

* Difference was significant ($P < 0.05$) from controls.

of interest because of the different levels of female hormone present in the animals of these three groups. Thus, the rate of gain of these groups was proportional to the amounts of estrogens present. The testosterone-treated heifers appeared to get a temporary growth stimulus from the male hormone. It is probable that the intramuscular injections were metabolized or destroyed making the effect one of short duration. However, pellet implantation (50 mgm. per animal) in Experiment II did not produce any different effects. There appeared to be some increase in growth for about 45 days after initial implantation.

Thiouracil, at the level administered, did not have any apparent effects

on the growth rate, whereas thyroprotein gave an initial growth stimulus but the over-all gains were reduced

The heifers in the second experiment did not make as rapid gains as did those in Experiment I. The animals used in Experiment II graded as "good" feeders whereas those used in the first experiment were "choice" feeders. However, animals on the same treatments in the two experiments responded similarly.

Feed Consumption and Efficiency

Data on feed consumption and feed required per 100 pounds of gain are summarized in tables 1 and 2. For ease of comparison between groups, feeds were grouped into roughages, which included cob meal, hay, and where fed, silage (converted to hay basis) and concentrates, corn and soybean oil meal.

In experiment I the testosterone-treated and spayed groups had the largest daily feed consumption, whereas in experiment II they had the smallest daily feed consumption. However, in both experiments the spayed heifers required more feed per 100 pounds of gain than any other, except the thyroprotein group. The heifers receiving the stilbestrol treatment were easier to keep on feed and in the second experiment had the largest daily feed consumption. The heifers on this treatment required less feed per 100 pounds of gain than the other groups in both experiments. These heifers required 4.8 percent and 10.4 percent less feed per pound of gain than the controls and 25.0 percent and 16.9 percent less feed per pound of gain than the spayed group in experiments I and II, respectively.

Unfortunately, the data on feed consumption and efficiency of experiment I did not lend themselves to statistical analysis. The design of experiment II permitted statistical treatment of the data on this point. For this purpose the concentrates and roughages were converted to a total digestible nutrient basis using Morrison's tables (1936). When by the method of covariance (Snedecor 1946) the TDN consumed were corrected to a constant level, the differences in gains were not significant, although analysis of variance of difference of gains proved to be significant at the one percent level. This may be interpreted to signify that the increased gains were mainly due to a greater feed consumption. This is not borne out by the spayed group in experiment I, which not only had the greatest feed consumption but was the least efficient in feed utilization. When a correlation was calculated between TDN consumed and TDN per 100 pounds of gain for the four groups, control, spayed, stilbestrol, and testosterone, there resulted a highly significant negative correlation ($r = -0.78$). Analysis of variance of total feed consumed was significantly different at the 5 percent level. From

these data it can be concluded that stilbestrol and to a lesser extent, testosterone, increase appetite.

Feeding of thiouracil, 4 gm. per head daily, did not affect feed consumption nor feed efficiency. The feeding of thyroprotein, ½ gm. per 100 pounds liveweight daily decreased feed efficiency. Rapid respiration, coughing, nasal discharge, and pneumonia were observed in this group.

A comparison of the feed required per 100 pounds of gain for both experiments shows that the heifers in experiment II were less efficient than those in experiment I.

Carcass Studies

There were no significant differences as results of treatment in carcass grade nor dressing percentage in these two experiments. The carcasses from the stilbestrol-treated heifers were slightly "hooky" but not enough so to affect carcass grade.

Sexual Behavior

The heifer calves used as controls in these experiments exhibited infrequent and irregular estrual periods. The stilbestrol-treated groups showed extreme hyperemia and swelling of the external genitalia within a week following treatment and estrual periods which lasted from 10 to 14 days. During this time the heifers developed a typical "nymphomaniac stance," that is, stood with tail heads elevated. This stance persisted throughout the feeding periods. Following the initial estrual response, estrus was irregular. The administration of the male hormone produced a restlessness and nervousness and it was difficult to determine the occurrence of estrus.

Thiouracil treatment had no apparent effect on the estrual cycle while thyroprotein feeding seemed to decrease the number of days in estrus.

At the time of slaughter all ovaries were more or less grossly normal. However, by this time the effects of treatment might not be evident. The presence of corpora lutea in the ovaries indicated that ovulation had been occurring and numerous Graafian follicles were observed. However, the ovaries from the groups receiving the sex hormones, and also thyroprotein, had greater numbers of small follicles (2 to 5 mm.) present.

Mammary Development

It has been demonstrated that stilbestrol will cause mammary development in virgin heifers (Walker *et al.*, 1941). All heifers receiving the stilbestrol treatment in both experiments showed pronounced mammary and teat development not exhibited in the control groups. The teat and udder development 90 days after the beginning of treatment was comparable to

that seen in late gestation in beef heifers. Towards the end of the experimental period the udders were less distended and there appeared to be a slight regression. Some of the testosterone-treated heifers may have had slight mammary stimulation but no teat development.

Blood Studies

The stilbestrol-treated group of heifers had significantly lower ($P<0.01$)) erythrocyte counts, 7.86 ± 0.16 as compared to 8.53 ± 0.19 for the normal

TABLE 3. EFFECT OF HORMONES ON SOME BLOOD CONSTITUENTS OF BEEF HEIFERS†

Experiment I					
Treatment	Control	Spayed	Stilbestrol	Testosterone	Thiouracil
Erythrocytes (Millions per cc.)	8.53 ±0.19	8.73 ±0.19	7.86** ±0.16	8.33 ±0.15	8.87* ±0.23
Cholesterol (Mgm. %)	116.4 ±3.3	113.3 ±3.5	104.3 ±2.4	119.3 ±4.0	111.7 ±3.7
Experiment II					
Treatment	Control	Spayed	Stilbestrol	Testosterone	Thyro-protein
Lipid (Mgm. %)	226.5 ±9.7	285.0* ±9.1	220.3* ±7.3	212.4* ±8.0	203.1* ±6.7
Inorganic Phosphorus (Mgm. %)	8.2 ±0.04	8.1 ±0.06	8.7** ±0.03	8.5** ±0.04	9.0** ±0.04
Serum Calcium (Mgm. %)	11.99 ±0.14	11.84 ±0.72	11.89 ±0.15	12.11 ±0.14	12.19 ±0.14

† Averages for experiment with standard error.
* Difference was significant ($P<0.05$) from controls.
** Difference was highly significant ($P<0.01$) from controls.

control and 8.73 ± 0.19 for the spayed group. This is in agreement with findings reported for laboratory animals (Steinglass, *et al.*, 1941; Korenchevsky and Hall, 1944). The testosterone propionate group with red cell counts of 8.33 ± 0.15 did not show the stimulation of erythropoiesis as reported by Overbeck (1946) for guinea pigs, nor Taber, *et al.* (1943) for chickens. Treatment with thiouracil apparently stimulated erythropoiesis because the average value for this group, 8.87 ± 0.23 is the highest for any group. This was not as expected from reports of Domm and Taber (1946) that thyroidectomy resulted in a significant reduction in the red cells in the male but

not in the female fowl and that thiouracil reduced the red cell numbers in cocks, hens and capons.

The plasma cholesterol values of the heifers in this experiment did not show any significant differences between treatments.

Blood lipids were measured by the method of Allen (1933). The results, table 3, show differences between treatments to be significant at the 5% level. The values for the spayed group 285.0 ± 9.1 mg. percent are much greater than those for any other group. In an effort to find an index to the state of fattening a correlation was calculated between daily gains and blood lipid. These calculations indicated no correlation ($r = 0.13$, necessary for significance at 5% level 0.21). This was suspected because the spayed animals, although showing high blood lipid values were making the poorest gains. Unfortunately, the method of Allen does not include the phospholipid in the lipids measured. This may change an otherwise related correlation. No analysis for the phospholipid content of the blood was made in this experiment. The values obtained for these beef heifers are somewhat higher than those reported for growing dairy heifers of the same ages (Allen, 1938) and are closer to those reported for cows in lactation. It is possible that the higher level of energy intake of the beef heifers accounts for these variations.

Average values of blood serum calcium varied from 9.63 to 13.64 milligram percent. There were no significant differences between treatments. The values reported are in agreement with those reported for cattle by Knox *et al.* (1941) and Payne *et al.* (1946).

The differences between treatments for blood phosphorus are highly significant, being highest in the thyroprotein group and lowest in the control and spayed heifers. Pre-treatment values were similar for all groups and thereafter there was a gradual decline in the phosphorus values with increasing age of the heifers. However, the hormone treated groups did not show as rapid a decline in blood phosphorus as did the control or spayed groups. Differences between periods of bleeding for analysis are also highly significant as measured by analysis of variance. This would indicate that with increasing age there is a gradual decline in blood phosphorus until maturity is reached. This has been demonstrated by Black *et al.* (1943). Lower values have been reported for mature animals as compared to young growing animals by Braun (1946) and Payne *et al.* (1946). Why the hormones, particularly thyroprotein and stilbestrol, retarded the decline of blood phosphorus to more mature levels is not known.

Summary

Growth rate, feed efficiency, and feed consumption were significantly increased by stilbestrol pellet implantation.

Spaying of heifers for the feedlot resulted in decreased rate of gain and decreased feed efficiency. No benefit was derived in the feedlot as a result of spaying.

Treatment of heifers with testosterone propionate appeared to stimulate growth, but the effect was of short duration for dosage levels used.

Feeding thiouracil, 4 gm. per heifer per day, did not noticeably affect growth rate, feed consumption, or feed efficiency.

Feeding thyroprotein at a level of 0.5 gm. per 100 pounds body weight per day decreased rate of gain and feed efficiency.

Erythrocyte counts were decreased as a result of stilbestrol treatments and increased as a result of thiouracil treatment. The differences were significant.

None of the treatments employed significantly affected blood cholesterol levels of beef heifers.

Spaying significantly increased the blood lipid content.

Serum calcium levels were not affected as a result of treatment, but the inorganic phosphorus decreased at a significantly less rapid rate as a result of treatment with stilbestrol or thyroprotein.

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INFLUENCE OF SHOWS ON PRODUCTIVE VALUES IN BEEF CATTLE[1]

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SHOWS set the standard of type in beef cattle. The effect of shows is gradual and cumulative. There is nothing resulting from a show, similar to the discovery of a new vitamin, which may revolutionize certain branches of the feed industry almost overnight. Nonetheless, shows, and the judging of cattle at shows, do over the years set the standard of type.

What Shows Do Not Do

I think we need to keep in mind a few things that shows and judging of livestock do not do. All judging is a series of compromises. In judging livestock at a show, the judge tries to get what he considers the most of the best in his top animal. Anyone who knows anything at all about livestock will realize that, in a good show, the champion is not better in every respect than the reserve champion. Another thing we need to keep in mind is that judging is not an exact science. Rather, it is a combination of an art and a science. It depends upon ability to see and evaluate properly the various characteristics that comprise type.

Shows do not, of necessity, sort out the best breeding animal. We have all heard some critics of shows point out that the winning animal does not always prove to be the best breeder. We need, however, to keep in mind the fact that the show is not only the final testing ground of the art and science of breeding but also of the feeding, grooming and showing of livestock. Those who breed, produce, and show livestock do not expect, necessarily, that the champion bull is the best breeding bull in the ring; the fact that the champion bull in a big show does not prove to be the best breeding bull is not a valid criticism of livestock shows. People who use that argument against shows argue by inference that the wrong kind begets winners just as often as does the right kind. In this they are absolutely wrong.

Questions About Shows

Have shows resulted in the production of cattle that make more efficient gains than cattle made fifty years ago? Do cattle gain faster than they did previously? Maybe not, but we expect cattle to get fat at a lighter weight

[1] This paper was read before the Extension Section of the American Society of Animal Production Meeting, November 25, 1949.

and younger age than was true in the past; and they do it. A 1000 lb. steer today is fat, and the one 25 years ago was not. Since fat is higher in caloric value, the steer of today might possibly require more feed per pound of gain than steers of 20 years ago and still be more efficient because he produces a higher type carcass—a carcass with a greater percentage of fat.

What about steer shows? Why do not winners on foot win in the carcass? If they do not, are not we wrong? Are they too fat?

A steer show is not a carcass show. If it is, why show on foot? A steer show should result in top placing for a steer that has the best combination of, first, those things demanded by the consumer through the packer, and second, those characteristics required for efficient development. In other words, the producer and consumer meet and get the animal that most nearly satisfies the requirements set by each of them.

Maybe an occasional steer is too fat. The only way to know if he will fatten is to give him a chance. The right kind, too fat, is no problem; all the producer has to do is to get that kind and sell him when he is fat enough.

What Shows Have Contributed

Coming back to the subject of the contribution that shows have made to productive values in cattle, one might claim for shows all of the advancement that has been made in beef cattle type and the production of beef over the years. How much of this credit should go to shows I do not know, but I do know that the growth of shows and the improvement of type have been going on at the same time. It is hard to separate one from the other and say that we would have just the type of cattle we have today had there been no shows, or to say that we would have the kind of cattle today that we had 100 years ago if we had not had shows in the meantime.

Responsibility of the Judge

It seems to me that for a show to mean anything we must first of all have a competent judge. We must have a man who has some notion as to type; certainly a competent judge will separate the right type from the wrong type, and that is about all one can expect in a show. We need not necessarily agree with the judge on his 1st and 2nd placings. If those who are watching a show would remember all of the top animals, that is the five or six tops in every class, and keep that type in mind, instead of worrying about whether one ought to have 1st or 2nd, then they will get a lot out of the show and get cattle type in mind.

What Should Not Be Done

We often hear the argument that if there is such a little difference between the 1st and 2nd prize animals, why not have the Danish system whereby the

first six or eight get blue ribbons and no distinction is made among them. We would all like to have blue ribbons, but we do not want to run the chance of getting a red ribbon. If we are about as good as the top one, we think we are as good. Let's forget this idea of trying to make it easy on everybody, and get ourselves back on the basis where all the cattle are valued by a competent judge and are lined up according to his idea of their value—right or wrong.

What Has Been Done

Shows have accomplished a number of things

1. They have set type and have undoubtedly accelerated change in type. It may be that the present type is a slower growing beast than the old type; but, although shows have emphasized the smaller type, they have at the same time caused selection so that the smaller, typier beast gains just as fast and as economically as did the old type.

In the early shows where breeders brought their cattle together for comparison and sale, this change was more rapid and dramatic than it is today. The relatively low heritability of the characters making up conformation and also the long generation interval combine to make improvement or change among the top animals relatively slow or almost imperceptible, and we became impatient.

If we want to see the changes that shows are making, we should forget the national shows and visit the small shows in the country where the quality of the cattle is low. Here we can see changes that are perhaps more rapid than changes effected during early times, because the producer has better animals to go to when he wants to change or improve his type.

2. Earlier, I avoided an answer to the question, "Do cattle gain faster and more economically than they formerly did?" Now I'll say "yes." The vast change that has come to the southeastern United States during the past ten or fifteen years is proof of that fact. The change is from nondescript animals to animals built to do a specific job.

3. Shows, as much or more than any other factor, have brought about selection for improved type and resulted in improved feeding methods. If they had done nothing else, perhaps this incentive for better feeding is sufficient justification for all the shows ever held.

What Can Be Done

Are there any changes that should be made in shows?

1. Perhaps in steer shows some class could be worked out to exphasize the steer that makes economical and fast gains. I believe that is important, and that belief has caused me to oppose weight classification for steers. That

sort of classification, in my opinion, officially disregards size as related to age.

2. A combination of placing steers as is done in most shows (first, second, etc.) combined with grading the steers before they leave the ring has some merit in shows for boys and girls. Perhaps a follow-up on carcasses would add to the educational value of the steer show.

3. The shows of breeding cattle might be altered so more emphasis is placed on economy of gain and on breeding ability. The get-of-sire class focuses attention on the prepotent sire, but this could perhaps be enlarged to include some considerations besides type.

4. Shows offer an opportunity for the greatest job of education that has ever been done in the livestock field. If the local adult shows and the junior shows have failed to do what is expected of them, who is to blame? You and I. I agree that shows have not done all that they might, but with them we have the people and livestock together—a perfect setting for a real job of adult teaching. Let us do such a job. Let us work toward better shows for better beef, rather than beef for better shows. Change shows? Sure! Abolish them? Never!

THE EXTENSION OF RECORD OF PERFORMANCE IN BEEF CATTLE

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A BEEF cattle improvement program has been initiated in the State of Washington that is showing favorable results. Experimental evidence brought forth by the U.S.D.A. stations at Beltsville and Miles City plus state experiment station findings has contributed the fundamental knowledge and methods for the promotion of a sound record of performance among the stockmen of the nation.

Washington State College began the record of performance program in 1946. However, early steps taken in livestock improvement included passing of laws to use only registered beef bulls of a recognized beef breed on the ranges. Many range associations appointed selection committees to pass on the quality of bulls. Out of this came standards of bull grading which have been in general use since 1945.

TABLE 1. WASHINGTON BULL GRADING PROGRESS REPORT 1945–49 (28 COUNTIES COOPERATING)

Year	Grade			
	A	B	C	D
	(number of bulls)			
1945	109	161	187	14
1946	159	233	145	13
1947	183	244	142	19
1948	144	199	100	7
1949	194	224	46	8
5 yr. total	789	1061	620	61

After this program had been in effect for a few years, stockmen began to become grade conscious. They began to select bulls from breeders producing a high percentage of A and B grade individuals. The breeder with C and D quality found his market vanishing. Consequently he began to take stock of his breeding program. Vigorous culling programs were undertaken and careful selection of outstanding sires were made. At this point several breeders became interested in record of performance as a further tool in

measuring the value of their animals. Using the work reported at Miles City and California, the project was started the fall of 1946.

The first cooperator, Mr. R. L. Rutter, Jr. of Ellensburg, tested two Angus herd sires. Ten calves of the same age from each bull were weighed and graded at seven months weaning age. They were put on a uniform ration and fed five months. They were then weighed and graded and the daily gain determined and type scores compared. Calves from one Angus sire made one-third of a pound more gain per day and graded a half grade higher than calves from the other sire.

Early in 1947 Washington State College began the project in cooperation with the Western Regional Beef Breeding Laboratory and placed the three college herds, Hereford, Angus and Shorthorn, under official testing.

The Extension Animal Husbandman's responsibility was to acquaint producers with the program and to work with county agents in setting up the program for interested stockmen.

The method of procedure from there was the outlining of scope and details in a memorandum of understanding with the cooperator as follows:

1) Cow herd and sires weighed and graded in early fall
2) Permanent record sheet made up for each sire and dam
3) Breeding season held as much as possible to months of June, July, August
4) Calves weaned, weighed and graded at seven months of age
5) Calves placed on a uniform ration under similar conditions for five months
6) Calves weighed and graded at end of five month feeding period
7) Rate of gain and type scores compared and analyzed.

In 1948 six more cooperators, including three Angus, two Hereford and one Shorthorn herd, were brought into the program.

The grading is done by a representative of the Animal Husbandry Department, the Extension Animal Husbandman and the county agent. Each man scores independently of the other. These scores are then averaged and become the type score for the permanent records.

As far as possible all calves of any one herd are fed and handled alike. Cows that do not produce enough milk to feed their own calves are culled. The final evaluation of the calves is based on weaning weights, gain during the feeding period and the scores on type.

The program is now reaching the commercial cattleman. Mr. John Goldmark of Okanogan started his herd of some 100 grade Hereford cows in the fall of 1948. Four bulls were selected and graded. Cows were divided into four pastures and each bull bred 25 cows. The first calf crop came the spring of 1949. This program was outlined on the regular range custom. The calves

were weighed and graded in November. After weaning they were fed as usual with the herd during the winter. In the spring of 1950 they are to be weighed and graded again and will be placed on pasture and range. In the fall of 1950 they will be brought in and weighed and graded at the time they leave the ranch for sale as long yearlings.

It is hoped that in the near future there will be enough record of performance cooperators that breeding stock can be bought generally from proven blood lines. It is also hoped that purebred advertisements will carry some actual facts on rate of gain and quality instead of all adjectives and claims based on show-ring winnings.

A STUDY OF SOME OF THE FACTORS INFLUENCING THE BIRTH AND WEANING WEIGHTS OF BEEF CALVES[1]

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THE importance of evaluating the breeding potentialities of domestic animals at an early age has long been recognized by livestock breeders. If phenotype at an early age is an expression of genotype, it should be possible to select superior individuals on the basis of their early performance. However, if the phenotype of an individual is dependent largely on factors other than genotype, an animal's performance at an early age is of little value as a criterion of selection. More information on the factors that influence birth and weaning weights of beef calves is needed to determine the effectiveness of selection based on these characters.

The purpose of this study was to gain information on the relative importance of some of the factors that influence birth weight, weaning weight, and gain from birth to weaning of beef calves, and to determine the value of each of these characters as a criterion of selection for the improvement of the performance of beef cattle.

Materials and Methods

The data used in this study were collected at the North Platte and Valentine Substations of the Nebraska Agricultural Experiment Station from experiments designed primarily to determine the effect of different wintering rations on the performance of breeding cows. The data were treated separately in all analyses in this study because of the differences in management at the two stations.

The North Platte data were collected over two periods. Thirty-three birth and weaning weights were collected during 1936, and a total of 248 birth weights and 237 weaning weights were collected from 1944 through 1947. Two sires were used during the 1936 period and four sires were used during the 1944-through-1947 period. Two of the sires used during the 1944-through-1947 period were used in all four seasons, while two of them were used in only three seasons. Three of these sires were related to each other; however, the covariance between them was small.

The calves at the North Platte Substation were dropped in March and April and ran with their dams on grass until they were weaned at about 200

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days of age. The calf weights were corrected to a constant age of 200 days by regression of weight on age as described by Snedecor (1946). However, very little correction was necessary in most instances, since the general practice of weaning the calves at 200 days was closely followed.

Data on 74 birth weights and 69 weaning weights were available from the Valentine Substation during the years 1935 and 1936. The calves born in 1935 were the offspring of four sires and the calves born in 1936 were the offspring of two of the sires that had been used the previous year. All of the calves used in this study were sired by purebred Hereford bulls and were out of high-grade Hereford dams. The sires used at the Valentine Station were not closely related to each other.

The calves at the Valentine Substation were dropped the last part of May and the first part of June and ran with their dams on grass until they were weaned at about 150 days of age. The weaning weights were corrected to a constant age of 150 days by regression of weight on age. There was little variation in the age of the calves at weaning; consequently, the correction in most instances was small.

Some of the cows dropped their first calf as two-year-olds and the remainder were first calved as three-year-olds. All cows calving in any season were the same age: this made it unnecessary to correct for age of dam in determining the heritability estimates, since the data were analyzed on an intra-year, intra-lot basis according to Snedecor (1946).

The paternal half-sib correlation was the only method used in estimating heritability of the traits considered, since no birth or weaning records were available on the sires and dams. The components of the mean square were separated by the method introduced by Winsor and Clarke (1940).

In the analyses to determine the heritability of birth weight, the weights were adjusted for the sex differences which were found at the two stations. Weaning weights and gain from birth to weaning were not adjusted because differences in sex were not significant for these traits.

In this study correlation and regression coefficients were determined for gain from birth to weaning, and weaning weight with birth weight. These coefficients were calculated on an intra-year, intra-lot basis.

Different calf-cow weight relationships were determined on the data gathered at the North Platte Substation during the 1944-through-1947 period and for the data collected at the Valentine Substation during 1935 and 1936. The simple correlation and regression coefficients determined were: weight of the calf at birth with weight of the cow at calving, weight of the calf at weaning with weight of the cow at weaning, and gain of the calf from birth to weaning with the gain of the cow from calving to weaning. In this analysis the weight of the calves taken within 24 hours after birth

and the weaning weights corrected to a constant age were used. The gain was the difference between the birth weight and the corrected weaning weight. For the North Platte data the weights of the cow were taken within 24 hours after calving and on the weaning date. For the Valentine data the weight of the cow on the last weigh-day before calving was used, since the cows were not weighed immediately after calving at this station. This varied from one day to about three weeks. The correlation and regression coefficients involving the weights of the cows before calving are probably

TABLE 1. NUMBER, MEAN, AND STANDARD DEVIATION OF CALF WEIGHTS BY SEXES AND STATIONS

Items	Stations							
	North Platte				Valentine			
	Number animals	Sex	Mean wt.	Stand. dev.	Number animals	Sex	Mean wt.	Stand. dev.
			pounds	pounds			pounds	pounds
Birth Weight	148	♀	69	8.8	33	♀	72	7.2
	133	♂	74	9.8	41	♂	76	10.0
	281	♀ ♂	71	9.6	74	♀ ♂	74	9.0
Gain from Birth to Weaning	146	♀	299	42.8	29	♀	252	40.0
	124	♂	297	53.7	40	♂	263	41.1
	270	♀ ♂	298	48.0	69	♀ ♂	258	40.8
Weaning Weight[1]	146	♀	368	45.1	29	♀	325	43.2
	124	♂	371	57.0	40	♂	339	46.5
	270	♀ ♂	369	50.9	69	♀ ♂	333	45.4

[1] Weaning weights were corrected to a constant age of 150 days for the Valentine data and to 200 days for the North Platte data by regression of weight on age.

larger than they would be if the calf weight were not included in the cow weight. The weight of the cow on the day the calf was weaned was used for the Valentine data. The gain of the cow at the North Platte Station was the difference between the weight taken immediately after calving and the weight at weaning, while the gain of the cow at the Valentine Station was the difference between the weight taken on the last weight-day before calving and the weight taken on the weaning date.

Correlation and regression coefficients were determined for various combinations of production records for the data gathered at the North Platte Substation for the 1944-through-1947 period and for the Valentine data. The correlation and regression coefficients determined for the North Platte

data were: second calf crop on first, third calf crop on first, and third calf crop on second for birth weight (adjusted and unadjusted for sex), for gain from birth to weaning, and for weaning weight.

The correlation and regression coefficients determined for the Valentine data were: second calf crop on first for birth weight (adjusted and unadjusted for sex), for gain from birth to weaning, and weaning weight.

Results and Discussion

The means and standard deviations of birth weights, gains, and weaning weights are presented in table 1. These data are listed by sexes and stations.

The male calves at North Platte were five pounds heavier than the female calves at birth. The difference between the means of the two sexes at Valentine was four pounds. The variations in the gains and weaning weights were large at both stations, as shown by the size of the standard deviations. Consequently, the differences between the means of the two sexes for gain and weaning weight were not significant at either station. Knapp and Black (1941) reported a highly significant difference between sexes for rate of gain during the suckling period. Koger and Knox (1945) found a highly significant difference between the weights of male and female calves at weaning time. In general the trend of the present data from the Valentine Station agrees with their findings, but the differences between the sexes are not significant. The North Platte data, however, are not in agreement with their findings.

As shown in table 2 the differences between sires were significant at the .05 probability level for birth weight, but not for gain from birth to weaning or weaning weight in either the North Platte or Valentine data. The theoretical composition of the mean square is also shown in table 2. Heritability estimates based on paternal half-sib correlations were obtained from these figures. For the North Platte data these estimates are 0.45, 0, and 0.26 for birth weight, gain from birth to weaning, and weaning weight, respectively. Heritability estimates of 1.00, 0.45, and 0.52 were obtained for birth weight, gain from birth to weaning, and weaning weight, respectively, for the Valentine data. Dawson, Phillips, and Black (1947) reported a heritability estimate of 0.11 for birth weight and an estimate of 0.23 was obtained by Knapp and Nordskog (1946). For weaning weight Knapp and Nordskog (1946) reported a heritability estimate of 0.12. The estimates of heritability as reported in this study may be questioned because of the small number of calves used to evaluate the sires in a lot-season.

Correlation and regression coefficients for gain from birth to weaning and for weaning weight with birth weight are shown in table 3. The simple correlation coefficients were 0.07 and 0.44 for gain from birth to weaning with birth weight for North Platte and Valentine, respectively. The correlation

TABLE 2. INTRA-YEAR, INTRA-LOT ANALYSIS OF VARIANCE OF WEIGHTS AND GAINS OF CALVES—(MEAN SQUARES ONLY)

Source of variance	Birth weight[1]		Gain from birth to weaning		Weaning weight		Theoretical composition of mean square
	D.f.	Mean square	D.f.	Mean square	D.f.	Mean square	
	North Platte						
Between years	4	405.8	4	55598*	4	61946**	
Between lots within years	12	285.1**	12	3047*	12	4799**	
Between sires within lots and years	43	104.8*	43	1352	43	1921	$A+kB^2$
Within sires, lots, and years	221	65.8	210	1448	210	1465	A
	Valentine						
Between years	1	603.7*	1	832	1	3176	
Between lots within years	6	17.8	6	4396	6	4728	
Between sires within lots and years	14	128.9*	14	1805	14	2357	$A+kB^3$
Within sires, lots, and years	52	60.9	47	1294	47	1606	A

* $P<.05$.

** $P<.01$.

[1] Corrected for sex differences (five pounds for females at North Platte and four pounds for females at Valentine).

[2] k is equal to the average number of progeny per sire. k is 4.66 for birth weight and 4.48 for gain from birth to weaning and weaning weight.

[3] k is 3.34 for birth weight and 3.10 for gain from birth to weaning and weaning weight.

coefficients were 0.27 for North Platte and 0.60 for Valentine for weaning weight with birth weight. As shown by table 3 the correlation and regression coefficients are somewhat higher for the Valentine data than for the North Platte data. These figures are somewhat variable between the two stations, but they are in general agreement with some of the figures reported by previous workers. The Arizona Agricultural Experiment Sta-

TABLE 3. INTRA-YEAR, INTRA-LOT CORRELATION AND REGRESSION COEFFICIENTS FOR GAIN AND WEANING WEIGHT WITH BIRTH WEIGHT

Items	North Platte			Valentine		
	D.f.	r	b	D.f.	r	b
Birth Weight with:						
Gain from birth to weaning	253	.07	0.31	60	.44**	1.88
Weaning weight	253	.27**	1.42	60	.60**	2.33

** $P<.01$.

tion (1937) reported a correlation coefficient of 0.60 between birth weight and average daily gain from birth to weaning for range calves. Dawson *et al.* (1947) found a correlation coefficient of −0.58 between birth weight and number of days required to reach 500 pounds. Kransnov and Pak (1939) found that the correlation between birth weight and weight at four months of age ranged from 0.39 to 0.58 for males and 0.43 to 0.48 for females.

Correlation and regression coefficients were calculated for different calf-cow weight relationships. The correlation of the birth weights of all calves and the weights of the cows immediately after calving was 0.21 for the North Platte data. The correlation of the birth weights of all calves and the weight of the cow on the last weigh-day before calving was 0.32 for the Valentine data. The correlation coefficients for calf gains from birth to weaning with cow gains from calving to weaning were −0.12 and −0.34 for the North Platte and Valentine data, respectively. Correlation coefficients for the weights of the calves at weaning and the weights of the cows at weaning were 0.20 for the North Platte data and −0.11 for the Valentine data.

These results agree fairly well with those reported by previous workers. Knapp, Lambert and Black (1940) reported a correlation coefficient of 0.22 for the weight of the calf at birth with the weight of the dam at calving. Kusner (1936) found correlation coefficients of 0.30 and 0.42 for the weight of dams with that of daughters at birth in two herds of Kazak-Kalmuck, Hereford cross cattle. Kransnov and Pak (1939) reported correlation coefficients of 0.56 for male calves and 0.42 for female calves between weight of the dam and weight of the calf at birth. Dawson *et al.* (1947) found a correlation coefficient of 0.49 between the weights of the dams and the birth weights of the calves.

The cows that were heavier than the mean weight at calving tended to give birth to calves that were heavier than the mean birth weight of all calves. The same condition existed for weaning weight for the North Platte data but not for the Valentine data. The negative correlation between gain of the calf from birth to weaning and gain of the cow from calving to weaning indicates that the cows making the smallest gains during the nursing period tended to produce calves that made the greatest gains. This may be explained on the basis that the cows making the smallest gains were probably doing so because more of their nutrients were going into the production of milk than into body flesh. The more rapid gains made by these calves probably were largely the result of the higher milk producing ability of their dams.

Correlation and regression coefficients for various combinations of production records are shown in table 4. The repeatability of yearly perform-

ance of the cow is much lower for birth weight than for gain or weaning weight. The repeatability of birth weight was higher when corrections were made for the sex of the calf. This would be expected since there were definite sex differences for birth weight in these data.

The correlation and regression coefficients for the repeatability of yearly performance are in general somewhat lower than those reported by

TABLE 4. WITHIN LOT CORRELATION AND REGRESSION COEFFICIENTS FOR VARIOUS COMBINATIONS OF PRODUCTION RECORDS OF BEEF COWS

Comparisons made	Stations					
	North Platte			Valentine		
	D.f.	r	b	D.f.	r	b
Birth Weight: Adjusted for Sex[1]						
Second on first	73	.244*	.202	28	−.031	−.033
Third on first	55	.212	.182			
Third on second	54	.114	.098			
Birth Weight: Unadjusted for Sex						
Second on first	73	.161	.131	28	−.112	−.116
Third on first	55	.206	.188			
Third on second	54	.067	.059			
Gain from Birth to Weaning:						
Second on first	69	.502**	.484	25	.569**	.529
Third on first	51	.384**	.419			
Third on second	51	.430**	.495			
Weaning Weight						
Second on first	69	.496**	.488	25	.431*	.330
Third on first	51	.347*	.412			
Third on second	51	.368**	.432			

[1] See footnote 1, Table 2.

* $P < .05$.

** $P < .01$.

Koger and Knox (1947). Their data included records on more animals over a longer period than were available for this study. They reported a correlation coefficient of 0.66 between the weaning weight of the first calf and that of the second calf. When the first weaning record was compared with the average of the second and third; the average of the second, third, and fourth; and the average of the second, third, fourth, and fifth records the correlation coefficients varied from 0.51 to 0.53.

The repeatability of the milk producing ability of the dam is probably an important factor in the repeatability of gain from birth to weaning and wean-

ing weights. This seems to be true because the environment of the calf prior to weaning apparently is a more important factor than the genotype of the individual in determining its rate of growth. On this basis it may be said that some progress can be made in increasing the weaning weights of the calves by culling cows on their first calving record, since this record seems to be a good indication of the milk producing ability of the dam. Similar conclusions were drawn by Koger and Knox (1947).

Summary and Conclusions

Studies were made on some of the factors affecting birth weight, gain from birth to weaning, and weaning weight of beef calves. Data are presented on the influence of sex, sire, weight and gains of the dam, and the inherent producing ability of the dam on these three characters. Data are also presented on the influence of birth weight on gain from birth to weaning and on weaning weight.

In these data there was a significant difference in birth weight between sexes. Such a condition did not exist for gain from birth to weaning, or for weaning weight. In general, however, the mean difference was in favor of the male calves.

Differences between sires were not significant for weaning weight or gain from birth to weaning, which may be due to the small number of sires used and the small size of the sire progeny group used to evaluate the sires. The heritability estimates obtained from paternal half-sib correlations were .45 and 1.00 for birth weight, 0.0 and .45 for gain from birth to weaning, and .26 and .52 for weaning weight at the two stations. The weight of the dam had a significant influence on the birth weight of her offspring. The correlation between the weaning weight of the calf and the weight of the cow at weaning was significant at the .05 level of probability for the North Platte data but was negative and not significant for the Valentine data. Also, the cows making the smallest gains during the nursing period tended to produce calves making the largest gains from birth to weaning. This was probably the result of increased milk flow among these cows.

Calves that were heavier at birth tended to maintain this advantage and thus be heavier at weaning.

Cows tended to repeat their previous performance for gain of their calves from birth to weaning and weaning weight of their calves to a higher degree than for birth weight. Since gain from birth to weaning and weaning weight seem to be influenced to a great extent by environmental factors, such as the milk flow of the dam; the repeatability of mothering ability, measured largely by milk flow, probably is quite high in beef cows.

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THE TENDERNESS OF BEEF IN RELATION TO DIFFERENT MUSCLES AND AGE IN THE ANIMAL

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TENDERNESS is the characteristic of beef most eagerly sought by consumers. They seek more specially tenderness in beef when cooked as steak or roasts. To utilize our beef more satisfactoritly than is done at present, it is desirable that we have knowledge of the differences in tenderness between certain representative cuts. The purpose of this study was to compare the relative tenderness of beef samples from 9 different locations of the carcass, and to compare samples from the same location in the carcasses of animals differing widely in age.

Many studies have been reported on differences in the tenderness of meat and the apparent reason. Mitchell, Hamilton, and Haines (1928) and Mackintosh, Hall, and Vail (1936) report a high correlation between connective tissue content and tenderness. Paul, Lowe, and MacClurg (1944) found that certain physical changes take place during refrigerated storage. Muscle fibers were well defined and wavy after 1 day's storage and showed rigor nodes. After 9 days' storage the fibers were broken and disintegrated. Ramsbottom, Strandine, and Koonz (1945) and Ramsbottom and Strandine (1948) reported a study involving 88 beef muscles from 3 steers of U. S. Good grade in which shear values ranged from 7.1 pounds for psoas major (tenderloin) to 16.3 pounds for the rhomboidens (a small muscle in the shoulder). After the muscles were dissected out, they were frozen at −34.4° C. (−30° F.) and stored from 1 to 3 weeks and then thawed and tested. Hiner and Hankins (1941) reported that beef samples stored at 0.6° to 1.6° C. (33° to 35° F.) for 5, 10, 15, 25 and 35 days became progressively more tender.

The samples used in the study reported here were from 52 animals slaughtered under uniform conditions and the carcasses were aged from 12 to 15 days at 0.6° to 1.7° C. (33° to 35° F.). The 52 animals consisted of 8 cows that averaged approximately 5½ years of age, 8 barren heifers 3 years old, 25 900-pound steers 16 months old, 8 500-pound steer calves 7 months old, and 3 veal calves 2½ months of age. The carcasses averaged in grade as follows: cows, Commercial; heifers, High Commercial; steers, Good; 500-pound weanling calves, High Commercial; and veal, Good.

After each carcass was chilled and aged for approximately 12 to 15 days at 0.6° to 1.7° C. (33° to 35° F.) it was cut into the primal cuts and 9 samples

were removed for study. Effort was made to distribute these samples throughout the carcass and to have each major primal cut represented by one or more samples. The samples were removed at the following locations: (1) neck, 6th cervical vertebra; (2) foreshank, through radius and ulna bone near joint; (3) 3d rib; (4) across humerus or round bone of chuck; (5) 8th rib; (6) 3rd lumbar vertebra; (7) psoas major (tenderloin) below 6th lumbar vertebra; (8) rise of pelvic arch (loin end); and (9) 1½ inches from cut surface or face of round. Each sample was cut 1½ inches thick and placed in the refrigerator overnight. Each set of 9 samples was from 1 side and each group of animals was represented by an equal number of samples from the right and left sides of the carcass.

As near the 14th day as possible, the prepared samples were weighed, placed in an electric oven heated to 200° C. (392° F.) and allowed to remain until the internal temperature reached 60° C. (140° F.). They were then tested for tenderness by means of the Warner-Bratzler shearing strength device.

The cylinders of meat for shearing—each 1 inch in diameter and parallel with the muscle fibers—were always removed from the same locations in the neck, foreshank, rib and other samples. The following numbers of cylinders were removed from each sample for testing: Sample No. 1, 5; No. 2, 4; No. 3, 3; No. 4, 5; No. 5, 3; No. 6, 3; No. 7, 3; No. 8, 7; and No. 9, 9. The sample of round, No. 9, was subdivided for study and 2 cylinders each were removed from the biceps femoris and semimembranosus muscles, 1 cylinder from the semitendinosus, and 4 cylinders from other muscles. Each cylinder was sheared 3 times and all shearings for each sample averaged to give a single value representing the tenderness of that particular sample.

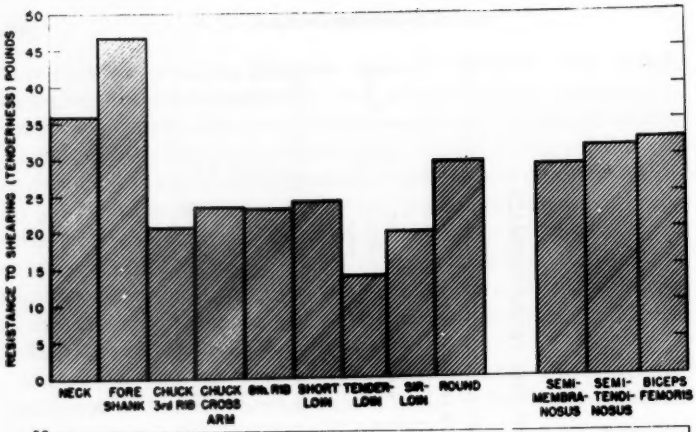
Experimental Results

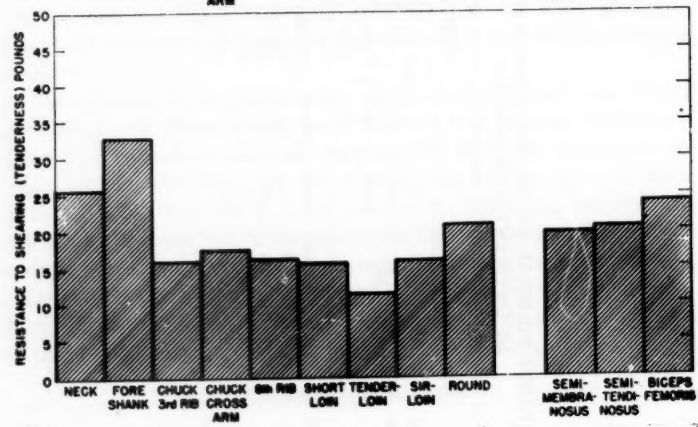
As shown in table 1 and figures 1 and 2, the 9 samples in each age group classified themselves into 4 degrees of tenderness as follows: the least tender was the neck and foreshank; next was the round; third, were the chuck, rib, shortloin and loin end, which among themselves did not always hold the same order; and finally, the tenderloin (psoas major), as expected, was the most tender.

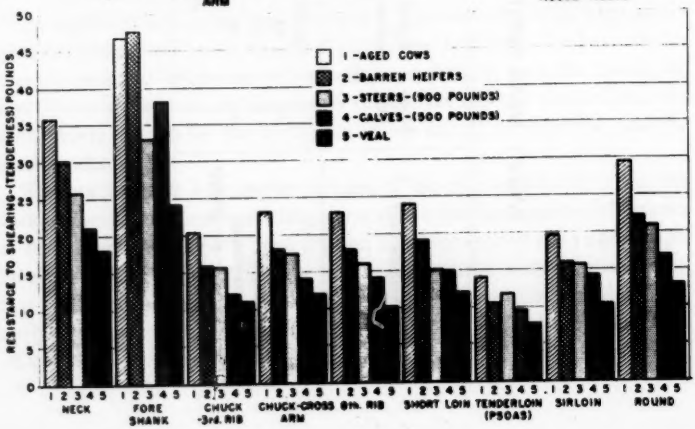
To obtain further information on some of the relationships involved, the various average tenderness readings were tested for significance of difference of the means, using the "T" test (Fisher, 1934) for each of the 5 age groups. Due to difficulties of sampling, the neck and foreshank were not included in this study. Also, the two samples from the chuck were not included. This analysis showed that the differences in mean tenderness between the round on one hand and rib, shortloin, tenderloin, and loin end on the other hand

TABLE 1. MEAN RESISTANCE TO SHEARING OF NINE SAMPLES OF BEEF FROM ANIMALS OF DIFFERENT AGES AND SEX

Animals used	Number	Age of animal	Meat aging period	Shearing resistance of—								
				Neck	Foreshank	Chuck		8th rib	Shortloin	Tenderloin psoas	Loin end	Round
						3rd rib	Crossarm					
		months	days	pounds	pounds	pounds	pounds	pounds	pounds	pounds	pounds	pounds
Cows	8	67	13.0	35.8	46.7	20.4	23.4	23.1	24.5	14.1	19.8	29.6
Heifers, barren	8	37	13.8	30.2	47.5	16.0	18.6	18.0	19.1	10.5	16.2	22.4
Steers—900 pounds	25	14	13.4	25.8	33.1	16.0	17.9	16.3	15.8	11.7	15.7	21.0
Steer Calves—500 pounds	8	8	12.8	21.2	38.1	12.7	14.3	14.7	15.5	9.6	14.4	16.9
Veal Calves	3	2.5	13.7	18.2	24.5	11.4	12.3	10.7	12.7	7.9	10.4	13.0


RESISTANCE TO SHEARING (TENDERNESS) POUNDS
0
5
10
15
20
25
30
35
40
45
50
NECK
FORE SHANK
CHUCK 3rd RIB
CHUCK CROSS ARM
6th. RIB
SHORT LOIN
TENDER-LOIN
SIR-LOIN
ROUND
SEMI-MEMBRA-NOSUS
SEMI-TENDI-NOSUS
BICEPS FEMORIS


RESISTANCE TO SHEARING (TENDERNESS) POUNDS
0
5
10
15
20
25
30
35
40
45
50
NECK
FORE SHANK
CHUCK 3rd RIB
CHUCK CROSS ARM
6th RIB
SHORT LOIN
TENDER-LOIN
SIR-LOIN
ROUND
SEMI-MEMBRA-NOSUS
SEMI-TENDI-NOSUS
BICEPS FEMORIS


RESISTANCE TO SHEARING-(TENDERNESS) POUNDS
0
5
10
15
20
25
30
35
40
45
50
1 -AGED COWS
2 -BARREN HEIFERS
3 -STEERS-(900 POUNDS)
4 -CALVES-(500 POUNDS)
5 -VEAL
1 2 3 4 5
NECK
FORE SHANK
CHUCK -3rd. RIB
CHUCK-CROSS ARM
6th. RIB
SHORT LOIN
TENDERLOIN (PSOAS)
SIRLOIN
ROUND

were all highly significant for cow beef. Highly significant differences of means were also found between loin end and shortloin, loin end and tenderloin, and tenderloin and all of the other four cuts. Only a significant difference was found between shortloin and rib and no significant difference between loin end and rib.

TABLE 2. RESISTANCE TO SHEARING OF SAMPLES OF ROUND AND OF SEMIMEMBRANOSUS, SEMITENDINOSUS AND BICEPS FEMORIS MUSCLES

Animals used	Number	Age of animal	Meat aging period	Shearing resistance of—			
				Round	Semimembranosus muscle	Semitendinosus muscle	Biceps femoris muscle
		months	days	pounds	pounds	pounds	pounds
Cows	8	67	13.0	29.6	28.9	31.4	32.5
Heifers, barren	8	37	13.8	22.4	23.1	26.0	26.0
Steers—900 pounds	25	14	13.4	21.0	19.5	20.6	24.1
Steer calves—500 pounds	8	8	12.8	16.9	16.7	16.6	17.4
Veal calves	3	2.5	13.7	13.0	15.3	13.2	12.5

As shown in table 1, for 3-year-old heifer beef the differences in tenderness between the five samples were not as great as those for older cow beef. The tenderloin muscle was the only sample in which the difference of its mean and the other four were highly significant. A significant difference of the means was found between round and loin end samples and between tenderloin and loin end.

For the 900-pound steers differences in tenderness between samples from the 8th rib, shortloin, and loin end were of no statistical significance. However, the mean difference in tenderness between the round and these 3 samples and the tenderloin were all highly significant.

Still less differences in tenderness were found between the samples from 500-pound beef calves. The tenderloin sample was the only one differing significantly from the others.

The differences in tenderness between the 5 veal samples studied were of no statistical significance. Apparently in young animals only small differences in tenderness are to be expected.

Fig. 1. Relationship between nine samples of beef and three round muscles from aged cows.
Fig. 2. Relationship between nine samples of beef and three round muscles from 900 pound steers.
Fig. 3. Tenderness relationship between samples from animals of different ages and sex.

The beef round is often divided into "inside," "eye," and "outside" portions. These portions were represented in this study by the semimembranosus, semitendinosus and biceps femoris muscles, respectively. As shown in table 2 and figures 1 and 2, there was little difference in tenderness between these 3 muscles within each age group. However, as a rule the semimembranosus muscle was slightly the most tender of the 3 muscles.

To determine whether one sample could be used to estimate the shearing resistance of the other eight samples from the carcass, coefficients of correlation were computed. The "r" values were with one exception of no statistical significance in the cases of cow, heifer and steer beef. A value of $.51 \pm .20$ was found between tenderness of the round and rib in case of cow beef. However, with samples from 500-pound steers and veal the values between the round and rib, shortloin, tenderloin and loin end were .68, .72, .74, and .37 for the former and .73, .78, .74, and .74 for the latter. But the probable errors were large in all cases.

As further shown in table 1 and in figure 3, the resistance to shearing increased consistently for the various samples as age of animal increased, except in the cases of foreshank and tenderloin where there were some irregularities. The resistance to shearing ranged from 24.5 to 47.5 pounds for foreshank, which was the extreme variation, and from 7.9 to 14.1 pounds for tenderloin where the variation was least. In terms of percentage, the resistance to shearing increased with age from the different samples as follows: neck 96.7 percent; foreshank 93.9 percent; chuck, third rib, 79.0 percent; chuck, cróss arm, 90.2 percent; eighth rib 115.9 percent; shortloin 92.9 percent; tenderloin 78.5 percent; loin end 90.4 percent; and round 127.7 percent.

A statistical analysis of these data showed that for all samples except the neck and foreshank, which were not included in this phase of the study, the difference in shearing resistance between the values found for cows and veal calves was highly or very highly significant. Comparing veal calves with the three intermediate age groups, it was found that in all instances except the 500-pound calves, the various samples of the older cattle were less tender to a significant or highly significant degree.

Summary

Nine samples of beef muscle representing the principal cuts were studied to determine their relative tenderness. A total of 52 animals were used grouped as follows: 8 5½-year-old cows; 8 3-year-old barren heifers; 25 900-pound steers; 8 500-pound steer calves; and 3 10-week-old veal calves. After approximately 14 days aging at 0.6° to 1.7° C. the carcasses were cut and the 9 samples prepared. They were cut 1½ inches thick, weighed, heated to an

internal temperature of 60° C. in an electric oven at 200° C. and then tested for tenderness. For each of the 5 age groups, the samples classified themselves into 4 tenderness groups as follows: (1) the least tender, neck and foreshank; (2) round; (3) chuck at 3rd rib and across humerus bone, 8th rib, shortloin and loin end; and (4) the tenderloin.

Less difference in tenderness was found between samples representing veal or 500-pound steer calves than in those from the older, more mature animals, according to a statistical analysis.

The 3 large muscles of the round—semimembranosus, semitendinosus, and biceps femoris—were not significantly different in tenderness.

Correlation coefficients showed no close relationship between different samples within the same age group with respect to tenderness.

As the age of the animals increased tenderness decreased for each of the 9 samples. The difference between veal and cows was highly significant, whereas that between veal and beef from 500-pound steer calves was not.

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SOME RELATIONSHIPS BETWEEN CHEMICAL COMPOSITION, NUTRITIVE VALUE, AND INTAKE OF FORAGES GRAZED BY STEERS AND WETHERS[1]

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THE data reported in this paper represent a continuation and summary of experiments previously reported by Forbes and Garrigus (1948). Since the earlier publication, several papers bearing on this general subject have come to our attention. The literature on methods of measuring pasture-forage intake have been thoroughly reviewed by Saltonstall (1948). Extensive experiments have been reported by Homb (1946) on the relationship between roughage composition and its digestibility by lambs. Axelsson (1949) has summarized the relationships between composition of feeds and their digestibility, obtaining his data from Schneider's compilation (1946). Lancaster (1949) has proposed that fecal excretion of nitrogen be used as a tool for measurement of pasture-forage intake. The use of forage protein content as an indicator of digestibility has been investigated by Forbes (1950). Reid (1949) has reported the use of naturally occurring chromogen in a manner analogous to the lignin-ratio method for measuring digestibility and intake of forages. This method shows promise of being extremely useful.

Experimental

The methods and animals used were similar to those previously described by Forbes and Garrigus (1948). Intake and digestibility of nutrients by grazing steers and wethers were measured by the lignin-ratio technique, using the Ellis, Matrone and Maynard (1946) method for lignin analysis. Proximate analyses were made by accepted procedures on air-dried forages and feces, except that nitrogen was determined on fresh steer feces.

Collection periods were of eight days' duration following a five- to seven-day preliminary period. In order to minimize the effect of changing chemical composition of the forage, daily samples were taken starting three days before the first feces collection and continuing until three days before the last collection.

The steers used were grade Hereford, purchased on the local market at the start of each season, and weighing about 625–650 pounds. The wethers

[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station, and is reported by permission of the director.

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were either yearlings or lambs out of western ewes and by Southdown rams. The yearlings weighed about 90 pounds and lambs about 60 pounds at the start of each grazing season.

The forages used during 1947 were described previously (Forbes and Garrigus 1948). During 1948 the same plots were used for steers that had been used by steers and wethers in 1947, and in addition, bluegrass and ladino clover plots not used in 1947 were grazed by steers. All plots grazed by lambs in 1948 were plantings made in the fall of 1947, except for the bluegrass and ladino trials which were conducted on the same areas grazed by steers. The same plots used in 1948 were again used in 1949 except for the ladino clover. In addition, Kenland and Kentucky 215 red clovers were grazed after having been seeded in the spring of 1948. A total of 22 steers and 36 wethers was used.

TABLE 1A. SUMMARY OF RESULTS OF STEER GRAZING TRIALS

Trial and number of animals	Composition of forage (dry basis)						Digestion coefficients					Intake of total organic matter lbs./day
	Protein	Ether extract	Crude fiber	Nitrogen-free ext.	Lignin	Organic matter	Protein	Ether extract	Crude fiber	Nitrogen-free Ext.	Organic matter	
	%	%	%	%	%	%	%	%	%	%	%	
Kentucky Bluegrass												
1 (3)	18.8	5.7	22.1	47.0	3.9	93.6	78	81	71	83	80	15.2
2 (3)	14.3	4.4	29.0	46.8	6.9	94.6	63	66	50	73	69	12.0
3 (3)	16.2	5.7	27.5	44.1	6.0	93.5	73	72	63	71	71	13.1
4 (3)	12.4	4.4	27.3	50.4	7.1	94.5	59	67	63	69	66	13.3
8 (8)	20.3	6.5	21.3	46.5	4.5	94.6	76	78	70	81	79	14.6
9 (4)	12.0	4.3	26.1	52.0	7.6	94.4	61	63	55	68	65	14.5
10 (3)	19.4	5.0	22.7	46.8	4.8	93.9	79	73	68	79	77	15.2
11 (3)	8.7	5.2	37.6	43.8	7.4	95.3	43	72	38	56	60	15.3
Kentucky 31 Fescue												
1 (4)	15.5	5.2	24.8	48.1	4.6	93.6	71	80	70	80	77	5.4
2 (3)	11.2	6.1	24.8	50.1	6.7	92.1	65	69	58	71	69	17.7
3 (3)	19.9	5.8	21.3	44.2	3.3	91.2	80	87	77	87	85	17.1
5 (3)	15.2	5.3	24.8	46.9	7.5	92.2	65	64	69	67	66	7.4
6 (3)	15.4	5.8	27.0	44.8	6.8	93.0	69	70	45	66	67	12.2
7 (3)	12.0	5.5	26.1	47.9	7.0	91.5	59	66	50	62	62	12.8
Orchard Grass												
1 (4)	16.6	5.8	23.1	47.9	4.5	93.4	78	81	71	82	81	21.8
2 (3)	14.9	6.8	25.8	44.3	8.5	91.7	68	68	53	61	64	19.1
3 (2)	19.0	6.5	23.3	45.4	5.9	94.2	72	75	60	78	75	13.5
5 (3)	16.9	7.6	23.3	44.3	5.6	92.1	73	72	66	73	73	18.4
Ladino												
1 (4)	27.0	5.3	10.8	49.3	3.1	92.4	84	78	73	93	86	25.1
2 (5)	21.6	5.8	16.2	46.7	3.7	90.3	82	77	73	77	83	22.8
Alfalfa												
2 (3)	21.6	3.7	17.5	50.6	5.9	93.3	75	53	32	80	71	21.5
3 (3)	21.5	5.0	12.3	54.2	4.6	93.0	80	44	54	87	79	16.9

TABLE 1B. SUMMARY OF RESULTS OF WETHER GRAZING TRIALS

Trial and number of animals	Composition of forage (dry basis)						Digestion coefficients					Intake of total organic matter gms./day
	Protein	Ether extract	Crude fiber	Nitrogen-free ext.	Lignin	Organic matter	Protein	Crude fiber	Ether extract	Nitrogen-free ext.	Organic matter	
	%	%	%	%	%	%	%	%	%	%	%	
Lincoln Bromegrass												
1 (3)	23.4	6.3	19.5	41.8	2.8	91.0	84	85	72	87	84	1340
2 (3)	22.6	5.3	21.0	42.5	3.4	91.4	81	81	64	82	81	1310
3 (3)	16.4	7.0	21.4	48.9	5.8	93.7	68	65	58	75	71	1140
4 (3)	15.5	6.8	23.8	45.7	7.6	91.8	61	62	43	65	62	950
5 (3)	19.1	6.0	24.1	43.8	4.9	93.0	80	76	58	77	76	800
7 (6)	17.2	6.6	28.3	39.4	5.6	91.5	72	77	68	71	73	1135
Orchard Grass												
1 (3)	13.6	5.2	25.2	46.4	3.8	90.4	77	83	67	82	81	1290
3 (2)	11.9	5.6	28.8	42.8	5.0	89.1	70	75	50	74	72	1170
4 (3)	11.5	4.5	31.1	44.0	6.5	91.1	55	74	14	65	64	790
6 (3)	22.3	6.6	20.4	41.8	3.7	91.1	81	83	66	82	81	1340
7 (3)	17.9	7.2	22.0	44.2	4.4	91.3	74	75	60	76	74	1285
9 (3)	13.9	8.0	24.5	44.2	6.3	90.6	70	71	57	69	68	1145
10 (3)	15.1	7.7	24.9	43.4	6.0	91.1	68	72	56	70	69	1015
11 (3)	15.0	7.9	24.3	48.1	7.6	91.3	64	61	49	62	59	985
12 (3)	21.5	7.5	17.2	45.1	5.5	91.3	73	71	55	73	72	750
13 (3)	11.8	5.8	27.1	47.2	6.9	91.9	56	67	41	64	63	850
14 (3)	8.8	4.6	33.3	46.4	8.2	93.1	46	67	17	55	57	920
Kentucky 31 Feacue												
1 (3)	14.5	5.6	25.2	44.7	3.6	90.0	77	80	78	80	79	1240
3 (3)	12.9	5.2	26.6	44.0	5.1	88.7	71	70	63	67	68	855
4 (3)	11.2	3.9	28.6	47.2	6.1	90.9	58	65	43	58	59	438
6 (3)	21.8	5.7	20.9	42.1	3.8	90.5	80	81	73	81	81	1075
7 (3)	18.2	4.9	23.4	44.7	4.2	91.2	78	79	70	77	77	1190
9 (3)	12.7	5.3	24.2	48.0	6.1	90.2	68	71	60	70	70	1055
10 (3)	13.6	6.4	24.3	46.9	5.4	91.2	67	69	63	69	66	865
11 (3)	12.9	6.9	23.5	47.0	6.1	90.3	64	66	62	68	67	820
12 (4)	18.7	6.2	19.4	46.7	4.4	91.0	75	76	72	79	77	897
13 (3)	13.9	4.8	25.0	46.7	7.8	90.4	62	63	50	61	61	663
14 (3)	9.8	4.0	28.3	50.8	8.8	92.9	43	60	28	56	55	552
Alfalfa												
1 (3)	33.5	4.4	13.5	42.8	3.8	93.6	87	65	61	87	83	1360
2 (3)	30.3	5.2	14.8	44.3	4.1	94.6	83	69	61	85	80	1340
3 (3)	19.6	5.8	23.4	42.8	6.8	91.6	71	56	45	77	69	1235
5 (3)	19.0	4.1	18.4	49.4	5.8	90.9	77	51	47	83	74	1910
7 (3)	21.6	4.9	20.1	46.6	5.8	93.2	68	62	27	72	67	940
8 (3)	21.4	4.0	20.6	47.1	5.0	93.1	76	64	18	80	73	1035
Ladino												
2 (3)	26.8	6.2	14.4	42.6	3.6	90.0	85	73	74	86	83	1265
3 (4)	20.6	5.0	14.4	41.0	3.6	90.0	86	71	63	84	81	1120
4 (8)	22.9	4.6	12.2	53.2	4.5	92.9	79	63	47	85	79	1820
6 (3)	21.6	3.6	15.8	48.7	7.3	89.7	67	53	8	74	66	1180
7 (6)	23.3	3.5	13.8	50.0	3.1	90.6	86	87	65	90	88	1620
Bluegrass												
2 (3)	11.5	4.2	27.7	51.4	7.3	94.4	59	51	43	56	54	735
3 (6)	18.6	6.0	21.2	47.7	4.6	93.5	79	72	65	77	75	2125
Timothy												
1 (6)	16.2	5.7	26.2	45.2	3.9	93.3	74	79	61	79	77	1260
2 (3)	13.1	5.0	24.9	50.3	5.3	93.3	67	73	47	75	72	1040
Red Top												
1 (6)	14.8	5.0	27.1	44.7	5.6	91.6	60	71	39	67	66	910
2 (3)	11.4	5.8	25.5	49.9	4.1	92.6	68	76	60	77	75	1260
Kenland Red Clover												
1 (3)	20.5	6.0	13.3	53.7	5.5	93.5	76	49	68	81	75	1060
2 (3)	22.7	5.9	17.3	46.2	4.5	92.1	80	58	69	86	77	1230
Ky. 215 Red Clover												
1 (2)	21.0	5.8	12.5	51.6	5.1	90.9	77	50	72	82	76	1100

In the management of all forages, care was taken to assure that the growth within the plot to be grazed was uniform, so as to minimize the chance of selective grazing and to simplify the matter of choosing a sample of forage similar to that being consumed by the animals. All plots were clipped after each grazing period and were then permitted to re-grow to suitable height before the next grazing. Plot areas were made large enough to assure a sufficient feed supply, yet small enough to discourage selective grazing. Animals were grazed in groups of two to eight, with three being the usual number.

Digestion and metabolism trials were also conducted with a number of these forages for the purpose of checking the accuracy of the lignin-ratio procedure and for determining the metabolizable energy of the fresh forages. These will be reported in detail in a separate paper.

Results and Discussion

The results are presented in three tables and eight graphs. To simplify comparisons trial averages, rather than individual data, were used. These and other pertinent data may be found in table 1.

The effect of variation in chemical composition of the forages on organic-matter digestibility was investigated by use of correlation and regression analysis. Organic-matter digestibility was used, rather than dry-matter digestibility, since a widely variable content of ash was noted in the feces; animals grazing young forages were likely to have 20 to 25% ash in their feces, while feces from animals grazing more mature forages commonly contained 12 to 15% ash. The use of the factor, 2.25, for approximating the energy value of digestible ether extract is not justified when dealing with highly pigmented plant material; thus the use of organic matter, rather than dry matter or total digestible nutrients, seemed the most suitable measure of the digestible energy-yielding capacity of the forages.

In table 2 are shown the regression equations, standard error of estimate (Se) of the equations, standard error of the regression coefficients (Sb), coefficients of correlation, Student's "t," and probabilities as applied to all forages analyzed together. These data indicate the relationships between organic-matter digestibility and protein, crude-fiber, and lignin percentages in the dry matter of the forages, and show the relationships obtained between lignin content and intake of total organic matter and of digestible organic matter.

A study of the table reveals that the relationship between organic-matter digestibility and lignin content exhibits the greatest degree of correlation, the greatest regression coefficient, and the highest statistical significance. This demonstrates clearly that for purposes of predicting organic-

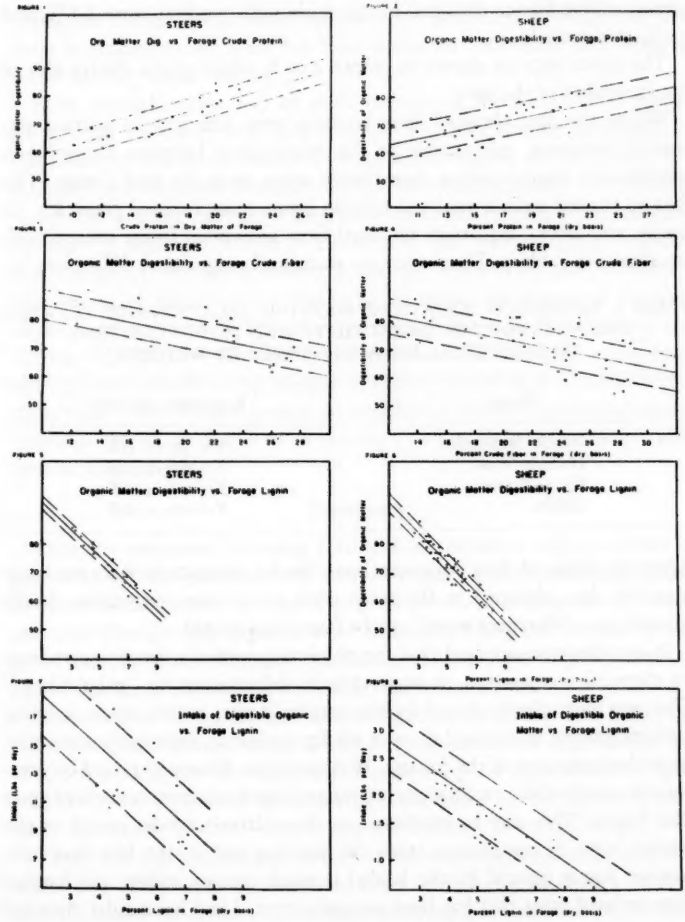
matter digestibility of a pasture forage, the best single measure is the lignin content of the forage. This is an entirely logical and expected finding in view of the non-digestibility of lignin and of the fact that, occurring in plant cell walls, it physically inhibits the digestion of nutrients enclosed within the cells. The fact that the protein content indicates the next best measure is probably more related to the high degree of negative correlation between lignin and protein contents than to any specific effect of protein itself upon total digestibility within the limits encountered in these experiments.

TABLE 2. REGRESSION EQUATIONS AND STATISTICS SHOWING RELATIONSHIPS BETWEEN ORGANIC MATTER DIGESTIBILITY AND INTAKE VERSUS CHEMICAL COMPOSITION OF FORAGES GRAZED BY STEERS AND WETHERS

	Regression	Se	Sb	t	r	P
Relation of organic matter digestibility (Y) to:						
Protein						
Steers	$Y=48+1.49X$	4.4	.22	6.8	+.84	<.01
Wethers	$Y=53+1.07X$	5.6	.15	7.1	+.72	<.01
Crude Fiber						
Steers	$Y=96-1.00X$	5.3	.20	5.0	−.74	<.01
Wethers	$Y=94-1.01X$	6.3	.18	5.6	−.64	<.01
Lignin						
Steers	$Y=100-4.71X$	2.4	.34	13.9	−.95	<.01
Wethers	$Y=100-5.24X$	3.1	.31	16.9	−.93	<.01
Relation of Intake of Total Organic Matter to Forage Lignin Content						
Steers	$Y=24.0-1.38X$	3.6	.51	2.7	−.53	>.05
Wethers	$Y=3.84-.26X$	.6	.06	4.3	−.53	<.01
Relation of Intake of digestible organic matter to forage lignin content						
Steers	$Y=22.2-1.81X$	2.8	.39	4.6	−.71	<.01
Wethers	$Y=3.43-.31X$	.5	.05	6.5	−.69	<.01

The difference between regression coefficients of organic-matter digestibility on lignin content obtained for steers and for wethers has a t value of 1.15, showing that these species of animals have similar digestive capacities (t required for odds of 19:1 with 70 degrees of freedom equals 2.00). The same conclusion may be reached through consideration of the regression coefficients of organic-matter digestibility on protein and on crude fiber contents. In neither case are the results obtained for the two species statistically different.

Another interesting similarity between the steers and wethers is apparent from a study of the effect of lignin in the forage on the intake of forage and of digestible organic matter by the grazing animals. These relationships



are less closely correlated than the digestibility data because of the additional and uncontrolled factors, such as weather conditions and previous treatment of the animals, which may effect the intake of feed by grazing animals; nevertheless a definite trend is shown. The data obtained in trials with steers show that for each percentage unit increase in forage-lignin content there was a decrease of 5.8% of the maximum intake in the total organic matter and of 8.2% in the digestible organic-matter intake. The

corresponding figures obtained in the trials with wethers were 6.8% and 9.5%, respectively.

The above data are shown in graphs 1 to 8, which give a clearer idea of the variability of the data.

Where the data obtained from wethers were sufficient to warrant statistical treatment, calculations of the relationship between forage-lignin content and organic-matter digestibility were made for each forage. The data so treated include trials on Lincoln bromegrass, orchard grass, Ky. 31 fescue, and alfalfa. Equations obtained from individual forage comparisons are shown in table 3. There were no statistically significant differences be-

TABLE 3. REGRESSION EQUATIONS SHOWING RELATIONSHIPS BETWEEN ORGANIC MATTER DIGESTIBILITY AND LIGNIN CONTENT OF INDIVIDUAL FORAGES GRAZED BY WETHERS

Forage	Regression equations
Lincoln Bromegrass	$Y = 97 - 4.33X$
Orchard Grass	$Y = 100 - 5.32X$
Ky. 31 Fescue	$Y = 96 - 4.81X$
Alfalfa	$Y = 100 - 4.92X$

tween the slopes of these regression lines. Similar calculations were not made from the data obtained in the trials with steers since inspection clearly showed that differences would not be found (see graph).

It is commonly supposed that the physical nature of a forage, apart from its chemical composition, is important in determining its "palatability." This was most clearly shown by the wether lambs; in two years, yearling wethers grazing on orchard grass or on Ky. 31 fescue, apparently consumed equivalent amounts of the forages. Wether lambs, however, placed on comparable stands of the two forages, consumed significantly more orchard grass than fescue. This may be attributed to the relatively tender mouth of the wether lamb in comparison with the yearling and to the fact that midsummer fescue (grazed by the lambs) is much coarser, stiffer, and harsher than orchard grass that has been similarly treated and has similar chemical composition.

In the course of these investigations, digestion and metabolism trials were conducted periodically to obtain confirmation of the reliability of the lignin-ratio procedure, which is based on the premise that all lignin consumed may be recovered in the feces. These data will be reported in detail in a following paper, but mention should be made here that the average recovery of lignin from steers fed known amounts of fresh forage in digestion stalls was $106 \pm 5.8\%$, and from lambs the recovery was $111 \pm 8.7\%$. We have in-

vestigated the methoxyl content of the lignin isolated from forage and from feces in representative trials but have found no differences that could account for the "extra" lignin.

Some generalizations may be made concerning the adequacy of pasture for meeting the energy and protein needs of grazing animals by calculating the intake of digestible protein and digestible organic matter. Using as a standard the National Research Council recommendations for fattening 700-pound yearling cattle, 13.5 pounds of digestible nutrients in rations containing 7% digestible protein, it can be seen that the most likely deficiency is of energy, protein being present in the vast majority of cases in considerable excess of requirements. Similarly assuming, for 80-pound fattening lambs, a requirement of 853 grams of digestible nutrients in rations containing 7% digestible protein, the outstanding deficiency again is of energy, with protein usually being present in excess. These data indicate that in those cases when animals grazing on established pastures need supplements, emphasis should be placed on providing a high-energy rather than a high-protein supplement.

Summary

Data are presented showing relationships between organic-matter digestibility and the protein, crude fiber, and lignin contents of forages grazed by steers and wethers in a total of 70 grazing trials averaging over 3 animals per trial. Forages investigated were: Kentucky bluegrass, Lincoln bromegrass, orchard grass, Kentucky 31 fescue, timothy, red top, Kenland red clover, Kentucky 215 red clover, alfalfa, and ladino clover.

Steers and wethers exhibited similar digestive capacities. The best correlation between chemical composition and organic-matter digestibility was obtained with lignin. The regression of organic-matter digestibility on lignin content of the dry matter of the forage is expressed by the following equations: for steers, $Y = 100 - 4.71X$, and for wethers, $Y = 100 - 5.24X$.

There was also a significant correlation between digestible organic-matter intake and lignin content, data from trials with steers showing a decrease of 8.2% and from trials with wethers showing a decrease of 9.0% of the maximum intake for each percentage unit increased in lignin content of the forage.

The data also illustrate that when animals grazing on established pastures need supplements, emphasis should be placed on providing energy rather than protein.

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THE RELATIVE NUTRITIVE VALUE OF KENTUCKY BLUEGRASS, TIMOTHY, BROME GRASS, ORCHARD GRASS, AND ALFALFA[1]

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THE measurement of the nutritive value of pasture plants has become a subject of widespread interest, for the production and utilization of forage crops is of vital importance in the national system of agriculture. The measurement of pasture values, either by actual grazing with computation of the observed results into terms of digestible nutrients by the use of feeding standards in reverse, or by the quantitative collection of the forage and the computation of digestible nutrients by the use of assumed digestion coefficients, is a procedure subject to severe criticism. A feeding standard is in part an expression of the judgment of its author as to the nutritive requirments of animals but is usually made liberal enough to include the contingencies of practice such as effects of climate, variation in quality of feeds, and in the digestive, assimilative, and metabolic individuality of the animals. This factor of safety, properly included in a feeding standard, is not a part of the fundamental nutritive requirement of the animal. Actual maintenance requirements of animals on pasture are greatly influenced by weather conditions, by insect annoyance, and by the size and productivity of the pasture. There are no standard conditions of practice for determining these values.

Though no single approach can tell us all we may wish to know, it is the conviction of the authors that the soundest procedure in measuring the nutritional value of pasture forage is to cut the forage under conditions as closely representative as practicable of grazing by animals, and to feed the harvested herbage to animals under the relatively simple and controlled conditions of laboratory experimentation.

In attempting to compare the relative feeding value of various forages as reported in the literature, the investigator becomes keenly aware of the prevailing inequality of important factors influenceng results. These factors, seldom if ever the same in any two cases include weather, soil fertility, stage of maturity of the grass when cut, and conditions of drying for the production of hay. Any of these factors may be responsible for the variation encountered in the reported nutrient values of a single forage.

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Experimental Procedure

A project initiated in 1943 as a cooperative undertaking[2] was designed to produce 6 species of forages under like conditions and to evaluate these forages by feeding trials with sheep. A field on the college farm was divided into 36 plots, each 45 × 160 ft. with randomized distribution of 6 plots each of Kentucky bluegrass, orchard grass, timothy, brome grass, alfalfa, and ladino clover. These forages were grown on a residual soil derived from dolomite limestones similar to Hagerstown silt loam. The subsoil was a well drained, aggregated, silty clay.

The establishment of the plots as relatively pure stands was accomplished but further progress was prevented by the lack of a suitable hay drier until early in 1948 when a uniform method of drying the forages was made available by the construction of a drier designed[3] especially to meet the requirements of the project. At this time relatively pure stands of the four grasses were still available for study but the legume plots had become so weedy that in 1947 they had been plowed and re-seeded. Total yields were not recorded because it was felt that they would not represent normal production due to the infrequent fertilization during the war years. Sulfate of ammonia was applied at the rate of 40 lbs. of nitrogen per acre each spring and in 1948 a similar application was made immediately after the first cutting of the forages. Annual applications of 250 lbs. of 0–20–20 fertilizer per acre were made in the fall.

The first grass harvested, Kentucky bluegrass, was cut on May 20, 1948, at which time the head had emerged from the boot but had not expanded. It was found necessary to combine all 6 plots into one sample in order to obtain an amount sufficient for a feeding trial with 4 sheep. Later in the season (June 24) these plots were cut again, the forage obtained being enough for 3 feeding trials. The other three grasses were cut at a stage of maturity corresponding to that of the bluegrass on May 20, the dates of cutting being as follows: orchard grass, May 25–28; brome grass, June 1–3; timothy, June 14–16. Enough forage from each of the 6 individual plots of these 3 species was obtained to conduct a digestion trial with 4 sheep. In addition, a third cutting of orchard grass was obtained on August 2–3. A second cutting of alfalfa was harvested in 1949 at the 25% bloom stage for comparison with the grasses. A first cutting of orchard grass was also obtained on May 17, 1949 to compare with the samples secured during the previous year. Postponement of work with ladino clover was necessary on account of contamination from red and alsike clover for the first cutting and on account of dry weather thereafter.

[2] Departments of Animal Nutrition and Agronomy of the Pennsylvania Agricultural Experiment Station and the U. S. Regional Pasture Research Laboratory.

[3] Department of Agricultural Engineering, Pennsylvania State College.

TABLE 1. SCHEDULE OF EXPERIMENTATION

Period No.	Sheep group	Feed				Collection period		Calorimeter period		
		Kind	Plot	Amount daily, gm.	No. of sheep used	Start	End	Start	End	No. of sheep used
1	A	Timothy	A3	900	4	Oct. 22	Nov. 2	Nov. 3	Nov. 5	4
2	B	Timothy	A7	800	4	Oct. 29	Nov. 9			
4	D	Timothy	B20	800	2	Nov. 12	Nov. 23			
4	D	Timothy		700	1					
5	A	Timothy	C26	900	4	Nov. 26	Dec. 7	Dec. 8	Dec. 10	4
6	B	Timothy	C33	800	2	Dec. 3	Dec. 14			
6	B	Timothy	C33	600	1					
7	C	Brome grass	A5	800	3	Dec. 10	Dec. 21			
7	C	Brome grass	A5	700	1					
8	D	Brome grass	A11	700	2	Dec. 17	Dec. 28			
8	D	Brome grass	A11	600	1					
9	A	Brome grass	B16	900	3	Dec. 31	Jan. 11	Jan. 12	Jan. 14	3
10	B	Brome grass	B19	700	4	Jan. 7	Jan. 18	Jan. 19	Jan. 21	3
11	C	Brome grass	C30	600	3	Jan. 14	Jan. 25			
12	D	Brome grass	C35	600	4	Jan. 21	Feb. 1			
13	A	K. bluegrass	6 plots	900	4	Feb. 4	Feb. 15	Feb. 16	Feb. 18	4
14	B	K. bluegrass	A1	600	2	Feb. 11	Feb. 22			
15	C	K. bluegrass	3 plots	700	3	Feb. 18	Mar. 1	Mar. 2	Mar. 4	3
				600	1					
16	D	Orchard grass*	A2	700	4	Feb. 25	Mar. 8			
17	A	Orchard grass*	A8	900	4	Mar. 11	Mar. 22	Mar. 23	Mar. 25	4
18	B	Orchard grass*	B15	700	2	Mar. 18	Mar. 29			
19	C	Orchard grass*	B23	800	4	Mar. 25	Apr. 5	Apr. 6	Apr. 8	4
20	D	K. bluegrass	5 plots	800	3	Apr. 1	Apr. 12			
21	A	Orchard grass**	2 plots	900	4	Apr. 15	Apr. 26	Apr. 27	Apr. 29	4
22	B	Orchard grass*	C25	700	4	Apr. 22	May 3			
23	C	Orchard grass**	4 plots	800	4	Apr. 29	May 10	May 11	May 13	4
24	D	Orchard grass*	C36	800	3	May 6	May 17			
25	A′	Alfalfa	4 plots	1000	4	Sept. 30	Oct. 11	Oct. 12	Oct. 14	4
26	B′	Alfalfa	4 plots	1000	3	Oct. 7	Oct. 18	Oct. 19	Oct. 21	3
27	C′	Orchard grass***	2 plots	900	4	Oct. 14	Oct. 25	Oct. 26	Oct. 28	4

* 1st cut 1948.
** 3rd cut 1948.
*** Early 1st cut 1949.

The hay drier consisted of a 10×12 ft. shed containing steam radiators and an electric fan which forced air over the radiators and up through the material to be dried. The green forage rested on a floor of fine wire screening and was exposed to a temperature of about 180° F. for a period of three to four hours. The dried product was of excellent quality as judged by retention of color and leaves and by lack of woodiness in stems. The drier had a capacity of 800 pounds of fresh material and produced about 200 pounds of dried forage in approximately 4 hours. The dried forages were stored in large bags suspended from the barn loft.

In attaining the main objective of the experiment, the evaluation of the relative nutritive energy values of these common forages when grown and harvested under identical conditions, the metabolizable energy value appeared to be clearly the first choice of criteria by which these roughages

TABLE 2. COMPOSITION OF FEEDING STUFFS

Material	Period No.	Dry matter, %	Composition of dry matter					
			Crude protein, %	Ether extract, %	Ash, %	Crude fiber, %	N-free extract, %	Energy cal./gm.
Timothy	1	91.8	8.2	3.0	5.2	35.3	48.4	4513
Timothy	2	91.7	8.5	3.4	5.0	35.1	48.0	4547
Timothy	4	91.0	8.3	2.8	4.6	35.3	49.1	4542
Timothy	5	91.0	8.2	3.4	5.2	31.5	51.7	4514
Timothy	6	93.4	8.2	3.1	4.5	36.0	48.3	4549
Brome grass	7	91.3	12.2	3.3	7.1	32.4	45.1	4440
Brome grass	8	90.6	15.9	3.8	7.2	32.0	41.2	4516
Brome grass	9	88.7	12.6	3.7	6.9	30.5	46.3	4468
Brome grass	10	89.6	11.5	3.4	6.3	31.3	47.5	4478
Brome grass	11	88.7	11.8	3.7	6.5	29.7	48.3	4440
Brome grass	12	89.6	14.1	4.0	5.6	32.1	44.1	4553
K. bluegrass	13	90.7	17.8	4.5	7.0	24.4	46.2	4594
K. bluegrass	14	90.2	19.1	4.1	6.2	27.8	42.8	4733
K. bluegrass	15	89.9	18.5	4.0	6.1	27.7	43.7	4613
K. bluegrass	20	91.7	18.5	3.4	5.9	28.1	44.1	4615
Orchard grass*	16	87.7	11.8	3.5	7.6	30.8	46.3	4484
Orchard grass*	17	90.0	12.8	3.7	7.7	30.3	45.6	4477
Orchard grass*	18	89.4	11.5	2.8	7.5	28.3	49.9	4493
Orchard grass*	19	91.2	13.6	3.9	6.6	30.6	45.3	4518
Orchard grass**	21	90.6	20.6	6.0	7.7	26.0	39.8	4775
Orchard grass*	22	92.7	11.7	3.6	7.3	28.5	48.9	4454
Orchard grass**	23	92.0	20.8	5.3	8.0	27.1	38.8	4780
Orchard grass*	24	92.0	13.2	3.6	6.9	32.0	44.4	4491
Orchard grass***	27	91.6	17.9	4.9	6.6	27.2	43.3	4646
Alfalfa	25, 26	91.3	23.9	2.9	9.3	25.1	38.9	4614

* 1st cut 1948.
** 3rd cut 1948.
*** Early 1st cut 1949.

could be most practically and significantly compared. Metabolizable energy is simply the energy of the feed which becomes available to the animal and unlike total digestible nutrients its determination does not require that the feed and the feces be separated empirically into component parts which are subsequently put back together to constitute a "Total digestible nutrients"

value. Metabolizable energy values as pointed out by Kriss (1943) are "not much affected by the plane of nutrition within fairly wide limits above maintenance", and unlike net energy values, are not affected by activity and certain other factors which have nothing to do with a correct nutritive evaluation of the feed.

To permit a comparison of these forages on more than one basis, complete feed analyses were conducted on all samples of feeds and feces. Apparent digestibility values from which T. D. N. values are derived tacitly include the urine and methane as parts of the nutritive asset and only the feces are recognized as a loss. The determination of the energy content of feed and feces (digestible energy) by a bomb calorimeter is a direct, simple, and accurate procedure resulting in a nutritive measure comparable to total digestible nutrients. Although the determination of digestible energy avoids the laborious and empirical nature of the methods involved in the determination of total digestible nutrients, both measures possess the same limitation in significance with regard to the energy actually available to the animal.

In this study T. D. N., digestible dry matter, digestible energy, and metabolizable energy (feed energy minus the energy of the feces, urine, and methane) were determined on the five forages. Nineteen Hampshire wether lambs were obtained to serve as subjects from which 4 groups of 4 each were selected. Each group was treated as a unit so far as the calorimeter periods were concerned but each animal was quantitatively fed and digestibility data were obtained on individual sheep. These lambs were apparently in good condition when purchased but varied in weight from 41 to 88 pounds so that as a group they were not ideal for the experiment. So far as possible each group of 4 sheep was selected to give closely similar weights within the group. In most of the digestion periods and in all calorimeter periods the sheep within a group received identical quantities of feed.

The first 24 periods shown in the schedule of experimentation (table 1) refer to the year 1948, the last 3 periods to the year 1949. For these 3 periods another group of Hampshire wethers of very satisfactory uniform live weight was used. Collection periods were eleven days in length and ended the day before the sheep entered the calorimeter. The details of procedure were similar to those previously described (Swift *et al.*, 1948). An interval of at least 21 days elapsed between the end of one collection period and the beginning of the next one. During the first 7 days of this interval the sheep were turned loose in a pen to eat a mixed hay *ad libitum* while also receiving some grain. After one week the grain was withdrawn and the forage to be, tested was fed in an amount approximately equal to that which they could be depended upon to consume, and at the end of 7 more days the sheep were

TABLE 3. DIGESTIBILITY OF RATION CONSTITUENTS

Feed	Individual trials	Dry matter, %	Crude protein, %	Ether extract, %	Crude fiber, %	N-free extract, %	% Energy, %
Timothy	18	60.9	47.8	51.8	63.6	63.3	57.5
Alfalfa	7	61.9	74.5	19.3	48.9	73.0	61.0
Brome grass	21	70.6	66.0	55.0	74.0	73.0	67.3
Orchard grass*	21	72.8	67.8	52.8	77.3	75.1	69.6
Orchard grass**	8	69.7	77.3	43.5	75.4	68.8	66.1
Orchard grass***	4	71.1	71.8	52.1	74.7	74.0	68.1
Kentucky bluegrass	13	72.4	72.8	52.6	77.6	73.1	69.2

* 1st cut 1948.
** 3rd cut 1948.
*** Early 1st cut 1949.

placed in the collection crates to receive an exact constant daily amount of the same feed for a week (preliminary period) prior to the beginning of and throughout the collection period. The response of the sheep required an occasional slight deviation from this pattern. All individual feeds for an entire period were weighed to the nearest gram at the beginning of the preliminary period at which time a sample of the forage was taken for analysis. A total of 92 individual 11-day collection periods was completed.

Experimental Results

The composition of the forages (table 2) reveals that the third cutting of orchard grass as compared to the first cutting was much higher in protein and ether extract, and lower in crude fiber and nitrogen-free extract. A first cutting the following year cut 9 days earlier in the season showed similar differences but to a less marked degree. These three samples of orchchard grass, 1st cutting, 3rd cutting, and early first cutting were treated as separate units throughout the experiment.

Table 3 exhibits the digestibility of the forage constituents and the number of individual trials which were involved. The summary data in tables 3 and 4 are weighted or true averages. It will be noted that the lowest percentage digestibility of any ration constituent was found in either timothy or alfalfa. The low digestibility of the crude fiber of alfalfa (table 3) is rather outstanding when listed with comparable values for the other forages. This low digestibility of crude fiber and a high ash content (table 2) contributes toward a low T.D.N. value (table 4).

Attention is called to an apparent inconsistency in the digestible energy of the first and the third cuttings of orchard grass. Table 4 shows the digestible energy to be higher for the third cutting (per Kg. dry matter)

whereas in table 3 the percentage digestibility of the energy of the first cutting is appreciably higher (69.6 % vs. 66.1%). This apparent discrepancy occurs because the gross energy of the 3rd cutting per Kg. dry matter (4778 Cal.) is considerably higher than that of the first cutting (4486 Cal.) as shown in table 2.

The duplicate determinations of metabolizable energy per kilogram dry matter, each resulting from a group of either 3 or 4 sheep, averages of which are given in table 4, were as follows: timothy, 2098 and 2227 Cal., alfalfa, 2286 and 2295 Cal., brome grass, 2497 and 2540 Cal., orchard grass (1st cut), 2504 and 2522 Cal., orchard grass (3rd cut) 2534 and 2510 Cal., Kentucky

TABLE 4. METABOLIZABLE ENERGY, DIGESTIBLE ENERGY, DIGESTIBLE DRY MATTER AND TOTAL DIGESTIBLE NUTRIENTS

Feed	Per kilogram dry matter			
	Metabolizable energy, Cal.	Digestible energy, Cal.	Digestible dry matter, kg.	Total digestible nutrients, kg.
Timothy	2162	2600	.609	.606
Alfalfa	2290	2817	.619	.596
Brome grass	2516	3017	.706	.694
Orchard grass*	2513	3123	.728	.710
Orchard grass**	2523	3157	.697	.686
Orchard grass***	2574	3166	.711	.710
Kentucky bluegrass	2677	3196	.724	.714

* 1st cut 1948.
** 3rd cut 1948.
*** Early 1st cut 1949.

bluegrass, 2822 and 2427 Cal. These group determinations of metabolizable energy to which statistical treatment could not be applied were for the most part gratifyingly concordant with the exception of the values obtained for Kentucky bluegrass. Additional work is planned to verify the relative value of this grass in the nutritive assay although it is not anticipated that its position will be altered.

Thomas *et al.* (1948) have presented extensive results derived from several years of study with individual grasses, legumes, and combinations thereof. Yields, protein content, and management practices were recorded with pertinent observations regarding hardiness or persistency of stand. The forages were harvested to simulate grazing in some cases and in others to represent hay. Their finding that brome grass is winter hardy, becomes available for pasture early in the spring, and continues green during hot, dry weather lends added significance to its high metabolizable energy value.

Colovos *et al.* (1949) found a significant progressive decrease in protein content, protein digestibility, and metabolizable energy of early-, medium-, and late-cut timothy hays. Crampton and Jackson (1944) found the digestibility of pasture herbage was responsive to local climatic conditions of moisture and temperature and followed quite closely the leaf-stem ratio rather than time of year.

A statistical study by Student's method (1908) of the differences found with regard to digestible dry matter, digestible energy, and total digestible

TABLE 5. STATISTICAL COMPARISON OF NUTRITIVE VALUES OF FORAGES*

Basis of comparison	Kentucky bluegrass versus orchard grass 1st cut	Orchard grass versus brome grass	Brome grass versus timothy	Alfalfa versus timothy	Brome grass versus alfalfa	Kentucky bluegrass versus brome	Orchard grass versus timothy	Kentucky bluegrass versus timothy	Orchard grass 3rd cut versus 1st cut
Digestible dry matter	—	γ	γ	21	γ	—	γ	γ	γ
Digestible energy	—	γ	γ	γ	γ	1032	γ	γ	—
Total digestible nutrients	—	γ	γ	—	γ	γ	γ	γ	γ

* A numerical value in the table indicates the odds (to 1) that the first named forage is superior, a dash indicates no significance, γ indicates odds of more than 10,000 to 1.

nutrients (table 5) reveals a very high significance in the following comparisons; orchard grass (1st cut) and brome grass, brome grass and timothy, brome grass and alfalfa, orchard grass (1st cut) and timothy, and Kentucky bluegrass and timothy. A comparison of Kentucky bluegrass with orchard grass (1st cut) shows no significant difference by any one of the 3 methods of evaluation mentioned above. The differences found between orchard grass (1st cut) and orchard grass (3rd cut) are highly significant with respect to digestible dry matter and total digestible nutrients but not with respect to digestible energy. Comparison of alfalfa with timothy and Kentucky bluegrass with brome grass fails to show significant differences in at least one of the 3 criteria, namely, digestible dry matter, digestible energy, and total digestible nutrients.

It will be noted that the evaluation of these forages on the digestible energy basis, a simple procedure involving only heat of combustion determinations on the feed and feces with a bomb calorimeter, gives values which fall in an order similar to that for metabolizable energy. On the digestible energy basis orchard grass is about 3.5% superior to brome grass but ithis superiority though statistically significant is slight and the nearly identical

metabolizable energy values of these two grasses point toward equal nutritive value. The ratio of the energy of fecal dry matter to that of the feed is not the same with all feeds so that digestible dry matter cannot be looked upon as a critical measure of nutritive value.

In the determination of total digestible nutrients, the feed and feces are separated in a manner of speaking by empirical chemical analyses into component parts. The digestibility of each component (crude fiber, nitrogen-free extract etc.) is determined and in accord with their respective digestion coefficients the parts are reassembled to constitute a total digestible nutrient value expressed on a weight basis. The underlying energy aspect of the process is tacitly recognized by giving the same weight value to digestible protein and carbohydrate and by multiplying the digestible ether extract by 2.25 before including it in the T.D.N. appraisal. It is not surprising therefore that the last column in table 4 indicates a somewhat different ascending order of nutritive values when compared to the first 2 columns.

With the possible exception of digestible dry matter any criterion of feeding value shown in table 4 is, for practical purposes, on the energy basis. These criteria therefore do not take into account superior or inferior content of protein, vitamins, or minerals except as they may have affected the energy metabolism. The results as obtained indicate the available energy of these individual forages when fed alone. Their relative values as components of rations depend somewhat, of course, on the other ration constituents. However, it is the belief of the authors that the assay of these individual forages on an energy basis, made as far as possible under strictly comparable conditions, will serve as a useful guide, and that the relative position of each forage is firmly established as applied to sheep.

Summary

The nutritive values of timothy, alfalfa, brome grass, orchard grass and Kentucky bluegrass, harvested at comparable stages of maturity and dried under like conditions, were determined by 92 digestion and calorimetric experiments with sheep. Metabolizable energy values of these forages increased in the order named. Total digestible nutrients, digestible energy, and digestible dry matter were also determined. Highly significant in all 3 of these criteria was the superiority of brome grass over alfalfa and timothy; and orchard grass over brome grass, although in the latter case, when the methane and urine were taken into account, brome grass and orchard grass proved to be of equal value. A third cutting compared to a first cutting of orchard grass revealed a considerably higher content of protein and energy but digestion coefficients were lower for all feed constituents except protein.

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THE VALUE OF AVERAGE DIGESTIBILITY DATA[1]

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ONE of the most common methods employed to assess the nutritive value of feeds is to determine their content of *digestible* nutrients. To aid in the practical use of the digestible nutrient concept, there have been compiled tables presenting average proximate composition, average digestion coefficients, and average digestible nutrient values for a large number of feeds (Morrison, 1948; Schneider, 1947). If neither proximate analysis nor determination of digestibility can be carried out on a particular sample of feed, it is common practice to use directly the *average digestible protein* and the *average total digestible nutrient* values found in the tables. If proximate composition can be determined, then the table *average digestion coefficients* are applied to arrive at digestible nutrient values appropriate to the sample at hand.

Despite the fact that many research men and feed formulators routinely use the tables of average digestion coefficients which have been published, there are those who have expressed doubts as to whether doing so is advisable (Forbes *et al.*, 1937; Hamilton *et al.*, 1929; Hamilton and Kick, 1928; Lippincott and Card, 1934; Mitchell and Hamilton, 1933). A number of factors have contributed to these doubts, but a major one in most cases has been the wide variability in digestion coefficients which is commonly observed between samples of the same feed. Some critics apparently feel that, in view of this variability, average digestion coefficients aid little, if at all, in the assessment of the nutritive value of particular samples. Presumably, therefore, they would recommend that nutritive value be assessed on the basis of composition alone.

There are many who use average digestibility tables regularly when compounding rations. Research men continue to gather data on digestibility. As these many workers continue to accept average digestion coefficients in spite of the fact that others seriously question the value of average digestibility data, it seems important that the value of such data be investigated. The present paper, a statistical study of existing digestibility data, is such an investigation.

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Preliminary Considerations

The question to be answered is whether or not the nutritive value of a particular sample of feed is assessed more precisely by applying average digestion coefficients for that kind of feed than it is by considering composition alone. In order to develop a criterion for answering the question, it is necessary to point out that the use of composition alone is identical in consequence with the assumption that a given nutrient has exactly the same digestibility in all samples of all feeds. In contrast, the use of separate average digestion coefficients for each different feed may be said to assume only that digestibility is the same for all samples of the same feed.

For the present purposes it may be considered that the total variance in digestibility among all samples of all feeds is divisible into two parts: the between-feed component, σ_f^2, and the between-sample-within-feed component, σ_w^2. When composition alone is considered then, the precision with which nutritive value is assessed is

$$1/(\sigma_f^2+\sigma_w^2),$$

and when digestibility is considered, the precision is

$$1/\sigma_w^2.$$

The ratio of the latter to the former is

$$1+(\sigma_f^2/\sigma_w^2).$$

Thus, an index of the gain in precision to be obtained by using digestibility plus composition as compared to composition alone is provided by σ_f^2/σ_w^2, i.e., the ratio of the between-feed to the within-feed variances in digestibility. In the results to be presented this ratio will be expressed in the percentage form $100\ \sigma_f^2/\sigma_w^2$.

Data and Procedure

The data for this study were selected from the compilation used to calculate the average digestibilities given in the book, *Feeds of the World, Their Digestibility and Composition* (Schneider, 1947). The only criteria in addition to those followed by Schneider (1947) for selection of data were that each feed taken for this study had been investigated by at least two authors. Also, in all but three feed classes, in which feeding stuffs were accepted having as few as seven digestion trials per feed, only those feeds were selected on which there had been ten or more trials. If, in the results to follow, any certain common feed does not appear, it is because insufficient data were available as judged by the above criteria. In all, 194 feeds, on which investigations were published by 913 authors, were studied.

Before continuing, it is well to note that there is no point in studying the value of average digestion coefficients for distinguishing between quite dissimilar feeds. It is well known that feeds very low in protein exhibit low and even negative apparent digestibilities for protein. A similar situation exists for ether extract. In addition, those methods of formulating rations, that do not give explicit attention to digestibility, at least involve the classification of feeds into several major classes of relatively similar feeds, which classes differ considerably in digestibility for one or more nutrients.

As a result of the above considerations, the feeds to be studied were divided into five classes: hays, other dry roughages (straws, fodders, hulls, etc.), green soiling crops, silages, and concentrates. The data for each of the five classes of feeds were then further subdivided according to species of animal involved. Finally, a subdivision was made according to whether the digestibilities were obtained in trials where the feeds were fed alone, or were determined "by difference" when fed in combination with a basal ration for which digestibilities were determined in another trial.

On each of the above subclasses of data an analysis of variance was conducted with the following variance sources:

Between feeds
Between authors within feeds
Between samples within authors
Between trials within samples

The components of variance for the four sources were then estimated by the method of Ganguli (1943). The method provided directly the estimate of the between-feed component required for the numerator of the index of gain in precision developed above. The estimate of the within-feed component required for the denominator was then obtained as the sum of the estimates of the between-author, between-sample and between-trial components obtained in the above analysis.

Results

Estimates of the ratios of between- to within-feed variance in digestibility, expressed as percentages, are shown in table 1. The feeds included in each subclass are listed in footnotes. Before commenting on the results, it should be stressed that the estimates of the percentage, $100\ \sigma_f^2/\sigma_w^2$, which appear in the table, are subject to large sampling errors. As a result, detailed conclusions regarding individual values in the table should not be drawn by the reader. Rather, only the grosser aspects of the data should be noted. The negative values in the table are the result of sampling errors, because it is clear that one cannot obtain less precision in the long run by considering digestibility.

TABLE 1. ESTIMATES OF THE RATIOS OF THE BETWEEN-FEED TO WITHIN-FEED COMPONENTS OF VARIANCE FOR VARIOUS CLASSES OF SIMILAR FEEDS (EXPRESSED AS PERCENT)*

Class of feed	Animal species	No. of feeds	Feeds (footnotes)	Percentage increase in precision					
				Organic matter	Crude protein	Crude fiber	N.F.E.	Ether extract	T.D.N.
Hays:									
	Cattle	13	(1)	7	114	73	57	24	0
	Sheep	28	(2, 3, 4)	8	138	73	46	11	6
	Sheep-High Protein	11	(2)	1	43	7	− 1	17	3
	Sheep-Medium Protein	6	(3)	11	30	24	23	− 10	13
	Sheep-Low Protein	6	(4)	− 3	6	21	1	1	− 6
	Horses	3	(5)	55	115	33	96	20	37
Dry Roughages other than Hays:									
	Cattle	7	(6)	179	26	225	158	85	292
	Sheep	6	(7)	65	20	98	91	52	72
	Sheep	18	(8)	170	24	76	101	10	85
Silages:									
	Cattle	9	(9)	25	22	93	9	− 8	31
	Sheep	9	(10)	3	− 1	142	− 7	8	17
	Sheep	11	(11)	38	13	51	27	135	14
Green Soiling Crops:									
	Cattle	7	(12)	102	200	59	109	2	62
	Cattle	2	(13)	− 36	− 30	207	− 32	− 7	− 41
	Sheep	20	(14)	162	79	203	417	44	− 23
	Sheep	2	(15)	22	− 22	− 12	49	− 1	1
Concentrates:									
	Cattle	12	(16)	220	161	0	305	− 12	169
	Sheep	33	(17)	57	253	20	33	63	48
	Swine	2	(18)	175	2	214	95	62	377
	Swine	12	(19)	53	54	67	65	68	164

* Lines in italics represent those trials in which digestibility was determined "by difference," others are those in which feeds were fed alone.

(1) Alfalfa, alfalfa dehydrated, alfalfa clover timothy mixed, clover (undesignated), red clover, clover grass mixed, oat, soybean, soybean dehydrated, timothy suncured, timothy dehydrated, timothy grass weeds, mixed.

(2) Alfalfa, alfalfa dehydrated, alfalfa 1st cutting, alfalfa 2nd cutting, alfalfa 3rd cutting, bur clover, crimson clover, red clover, oat vetch mixed, soybean, common vetch.

(3) Bluegrass, clover mixed, clover grass mixed, red clover rye-grass mixed, oat pea mixed.

(4) Kentucky bluegrass, clover sweet vernal grass mixed, smooth brome, meadow fescue, oat, orchard grass timothy, timothy grass mixed.

(5) Alfalfa, alfalfa grass mixed, grass mixed.

(6) Corn fodder, corn stover, oat hulls, oat mill feed, oat straw, rice straw, wheat straw.

(7) Corn fodder, corn stover, oat straw, rice straw, sweet sorghum fodder, soybean straw.

(8) Barley straw, sugar beet tops, sugar beet tops dehydrated, sugar beet tops and crowns, cocoa shells, corn cobs, grape marc, spent hops, oat mill feed, oat straw, oat straw treated with NaOH, pea pods, peanut hulls, peat, potato tops, rye straw, winter rye straw, wheat straw.

(9) Alfalfa, red clover, clover grass mixed, corn lupine A.I.V., oat, soybean, sunflower, timothy.

(10) Alfalfa, bean, clover, clover grass mixed, corn grass, lupine, oat, pea, sunflower.

(11) Alfalfa, beet pulp, red clover, clover grass mixed, crimson clover, rye grass mixed, corn, grass, lupine, sunflower, tansy phacelia.

Viewing the table as a whole, it is noted the ratios are usually large. Thus, appreciable gains in precision may usually be expected if consideration is given to digestibility. The gains are marked for all nutrients in the case of concentrates and dry roughages other than hays. For hays, apparently very little gain in precision is to be expected for organic matter and T.D.N., but substantial gains may be expected for protein, fiber, and N-free extract digestibilities. Ether extract in hays shows only moderate gains. Note that when the hays are subdivided into groups on the basis of protein content, the gains observed for hays as a whole are considerably reduced. This suggests that a consideration of chemical composition in the assignment of digestibility figures to any given sample of feed will remove much of the advantage observed for using average digestion coefficients characteristic of each feed. The gains for silages and green soiling crops are somewhat erratic, but it appears that on the average moderate gains are to be expected for most of the nutrients in these two feed classes.

The possibility was noted above that a consideration of composition in assigning digestion coefficients would result in less advantage for separate digestion coefficients for each feed. In the course of the present studies this question was investigated using multiple covariance on proximate composition. The computational difficulties connected with the unbiased estimation of variance components, after multiple covariance, rendered such estimates unfeasible to obtain. Thus, only an approximate answer to this question was realized. The results indicate that there is less advantage in the use of separate digestion coefficients if composition is taken into account than if it is not, the gains being reduced to approximately half of those shown in table 1. There is no basis for concluding that the advantage will be eliminated by a consideration of proximate composition.

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(12) Red clover, clover grass mixed, corn fodder, grass mixed, Napier grass, sorghum, timothy.

(13) Mangels, potatoes.

(14) Alfalfa grass mixed, alfalfa 1st cutting, alfalfa 2nd cutting, Egyptian clover, clover grass mixed, corn fodder, sweet corn fodder, cowpeas fodder, mixed grass, white clover grass mixed, Guinea grass, marrow kale, sweet lupines, mallow, napier, peas, rape, soybeans, sunflower, common vetch.

(15) Carrots, mangels.

(16) Barley, corn, cottonseed, cottonseed meal, sorghum, linseed oil meal, oats, potato flour, soybean oil meal, sunflower seed oil meal hulls removed, sunflower seed oil meal with hulls, wheat bran.

(17) Barley, beans, beet pulp, blood meal, brewers dried grains, broomcorn grain, corn, corn bran, corn gluten feed corn gluten meal, pressed whole cottonseed, cottonseed feed, cottonseed meal, distillers dried grains, emmer, linseed oil meal, lupines bitterness extracted, oats, palm kernel oil meal, peanut oil meal, poppy seed oil meal, potato flour, rice bran, rye middlings, sesame oil meal, soybeans, soybean oil meal hydraulic or expeller process, soybean oil meal solvent process, ivory nut meal, wheat, wheat bran, yeast.

(18) Barley, corn.

(19) Barley, corn, sweet lupines, meat meal, meat and bone scrap, pork cracklings, potato flour, soybean oil meal, wheat bran, wheat flour middlings, wheat standard middlings, yeast.

Discussion

The results which have been presented show quite clearly that the use of tabulated average digestibilities for individual feeds in assessing the nutritive value of particular samples is warranted. Only in a few cases is there any evidence that one fails to obtain a more precise estimate of nutritive value by doing so, the comparison being made against any procedure which neglects digestibility altogether or distinguishes between feeds only as members of a major feed class. The gain in precision occurs despite the wide variability so often observed from sample to sample of a given feed and which has caused some workers to doubt the value of average digestibilities.

The wide variability just mentioned was observed in the present study, but this matter has not been taken up here. It will be discussed in detail in a later paper. The point might be made, however, that because of this wide variability, the advantage of using tabulated average digestibilities, although real, may not be as great as some students of the subject have believed.

In those instances where the increase in precision is large, there seems to be little question that a consideration of digestibility will always be worth while. In those cases where the increase in precision is small, some might question whether doing so is worth while. The authors are of the opinion, however, that digestibility values should be employed at all times in assessing the nutritive value of particular samples of feed. Certainly nothing can be lost and, as shown above, much may be gained by doing so. Further, digestion coefficients are not difficult to use.

It is logical to suppose that digestibility is in large measure a function of feed composition (and perhaps physical status), rather than a function of kind of feed involved, *i.e.* the coefficient of digestibility is not a constant intrinsic in a certain feeding stuff or plant species. As was brought out in the results, however, a consideration of proximate composition did not remove the advantage for basing digestion coefficients on kind of feed involved. A consideration of other nutrients might eliminate any advantage for considering individual feed digestibility. Until sufficient data on other nutrients (*e.g.* lignin, minerals, vitamins) are available to study the question, individual feed digestibilities will remain advantageous to use.

Summary and Conclusions

Using published data for five classes of feeds fed to four species of animals, the value of average digestibility data in the assessment of the nutritive value of particular feed samples has been studied by statistical methods. The criterion of value used was the ratio, expressed as a percentage, of the between and within-feed variances for digestion coefficients and

T.D.N. The ratio measures the relative increase in precision with which nutritive value is assessed if one uses separate digestion coefficients for each kind of feed, as compared to not considering digestibility at all or assuming that all feeds in a class have the same average digestibility.

The increases in precision if separate digestion coefficients are used may be expected to be moderate to marked for almost all nutrients in all feeds. If digestibility is adjusted for proximate composition the increases in precision may be expected to be reduced, but nevertheless will remain substantial. It was not possible to examine the effects of nutrients other than those included in proximate composition.

It was concluded that the practice of applying average digestion coefficients for a given feed to particular samples of that feed is warranted despite the fact that a high within-feed variability in digestibility is very common.

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EFFECT OF STILBESTROL ON THE GROWTH RATE OF SUCKLING LAMBS[1]

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THE administration of growth-stimulating hormones and drugs to farm livestock is attracting the attention of many research workers. The practice of administering stilbestrol pellets for caponizing cockerels, accelerating fat deposition, and tenderizing the meat of chickens has been accepted by many of the more progressive poultry men. Andrews and Bohren (1947), found with chickens that stilbestrol increased the efficiency of feed energy conversion to edible carcass calories by as much as 75 percent. Dinusson *et al.* (1949) reported that the simultaneous implantation of four 12-milligram stilbestrol pellets increased feed consumption, rate of gain, growth rate, and feed efficiency of fattening heifers. More recently, Andrews *et al.* (1949) reported that the subcutaneous implantation of either 12 or 24 milligrams of stilbestrol in pellet form resulted in highly significant increases in the gains of fattening lambs. The hormone-treated groups required significantly less feed per pound of gain than the control group.

Materials and Methods

Southdown, Rambouillet, and Columbia suckling lambs, which varied in age from 1 to 2 months, were obtained from the College flock in the spring of 1949 and used in this experiment. Twelve pairs of twin lambs, of which both members of the pair were of the same sex, were used in order to minimize genetic variation between lambs. However, it should be pointed out that both sexes were represented in the experiment. Individual weights were taken at the beginning of the experiment and each 14 days thereafter. One member of each set of twins was selected on a random basis and received a 12 milligram pellet of stilbestrol implanted in the shoulder just under the skin. In addition to their mothers' milk, the lambs were provided with grain and good quality alfalfa hay in a creep. The ewes were fed alfalfa hay, free choice, plus one pound of grain daily per head until May 15, at which time all the sheep were turned onto grass, and the creep feeding was discontinued. The treatment was not given to all of the lambs at the same time, but was given whenever the individual reached about 25 pounds in weight.

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[2] The authors express their appreciation to Wick and Fry, Inc., for the stilbestrol used in this experiment.

Consequently the time elapsing from treatment to the end of the experimental period varied from 91 to 105 days. The data on growth were analyzed statistically on a paired basis by the method of variance (Snedecor, 1946).

Results and Discussion

The effects of stilbestrol treatment on rate of gain in suckling lambs are summarized in table 1. The average daily gain by the treated lambs was .469 pounds, while the untreated lambs gained .478 pounds. This difference was not statistically significant. An analysis, not presented in this paper, indicated that there was no sex difference in the response to the treatment. Spencer, *et al.* (1931) noted that skulls and long bones of estrogen-treated rats of both sexes were smaller and their body length was greatly reduced. Apparently the dosage used in this experiment was not large enough to cause any dwarfing, as normal growth was made in all treated lambs, and there was no evidence of epiphysial closure.

TABLE 1. EFFECT OF STILBESTROL ON RATE OF GAIN OF SUCKLING LAMBS

Comparison	12 milligram stilbestrol	Controls
Number of lambs	12	12
Days on feed	91–105	91–105
Initial weight	24.0	25.0
Final weight	72.8	74.7
Total gain per lamb	48.4	48.8
Average daily gain	.469	.478

Close observation was made from time to time during the experiment on the testes of the treated ram lambs, and there appeared to be normal development. One of these males was selected in the fall and mated with five ewes and at the time of writing all of these ewes showed definite evidence of being pregnant. The vulva of the treated ewe lambs became quite swollen and inflamed for a period of about three weeks following the hormone treatment. Six of them were bred to a non-treated ram when they were about 9 months old and apparently all of them became pregnant.

While further experiments will be conducted to obtain additional data on this subject, the work at this station indicates that there is nothing to be gained by implanting 12-milligram stilbestrol pellets in young suckling lambs, as apparently the inherent capacity to grow is very high and cannot be accelerated by this treatment.

Summary

Subcutaneous implantation of 12 milligrams of stilbestrol did not increase the gain of suckling lambs of either sex during a feeding period that varied from 91 to 105 days.

The implantation of stilbestrol had no apparent dwarfing effect, and all treated lambs gained normally.

The ability of either male or female lambs to reproduce was not apparently impaired with treatments of this dosage at this age.

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THE EFFECT OF STILBESTROL ON FATTENING LAMBS[1]

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RESEARCH workers and practical livestock men see possibilities of growth-stimulating hormones increasing the efficiency of the livestock industry. The practice of administering stilbestrol pellets for accelerating fat deposition and tenderizing the meat of chickens is quite widely accepted. Dinusson *et al.* (1949) reported that the simultaneous implantation of four 12-milligram stilbestrol pellets increased feed consumption, rate of gain, growth rate, and feed efficiency of fattening heifers. The subcutaneous implantation of either 12 or 24 milligrams of stilbestrol in pellet form in fattening lambs, resulted in highly significantly increased gains and significantly less feed per pound of gain than the controls (Andrews *et al.*, 1949). Age apparently has an important bearing on the response that can be expected from stilbestrol when administered to lambs. Lambs treated by Jordan and Dinusson (1950) with 12 milligrams of stilbestrol in pellet form when the lambs were about two months of age showed no greater growth than the control lambs.

Materials and Methods

Two trials were conducted during the fall and winter of 1949–1950 to determine the effect of stilbestrol on the rate of gain, carcass quality, and feed efficiency of fattening lambs. Native, white-faced lambs, that averaged 4 months of age, were used in the first trial. Four lots of 13 lambs each were full fed from August 22 to November 5, a period of 74 days. The lambs were allotted into the 4 lots on the basis of their weight, sex, and general thriftiness. In the second trial, 50 seven- to eight-month-old cross bred lambs, that originated in western South Dakota, were divided into two lots. These lambs were placed in the experiment November 22 and full fed until February 22, a period of 92 days. They were allotted into their respective lots in the same manner as in the first trial. All of the lambs in both trials received a basal ration of No. 2 shelled yellow corn, soybean oil meal pellets (10% by weight of the corn fed), and brome hay. The lambs were fed in an open shed and had free access to fresh water, flake salt, and flake salt mixed with steamed bonemeal, 50-50. No attempt was made to equalize

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the feed intake, but rather an effort was made to determine the difference in feed intake of the various lots. The lambs in the second trial were sheared before being placed in the experiment.

The following experimental treatments were employed in Trial I:

Lot I Basal ration as outlined above, plus 12 milligrams of stilbestrol
Lot II Basal ration
Lot III Basal ration, plus 12 milligrams of stilbestrol
Lot IV Basal ration

The following experimental treatments were employed in Trial II:

Lot I Basal ration, plus 12 milligrams of stilbestrol
Lot II Basal ration

The stilbestrol was in pellet form and was implanted subcutaneously in the neck, just below the ear of the lambs, at the beginning of both trials. During the entire period of both trials the lambs received all the feed that they would clean up. Every effort was made to see to it that the lambs were kept on full feed. The grain was fed in the same feeder as the hay and any refused feed was weighed back night and morning. The data on daily gains and carcass grade were analyzed statistically by the method of variance (Snedecor, 1946).

Results and Discussion

The effect of stilbestrol on fattening lambs is given in table 1. In the first trial, the results of the treated lambs from Lots I and III are averaged together for ease of presentation. These lambs gained 0.43 pound per lamb daily over a 74 day period. The control lambs, Lots II and IV, gained 0.35 pound per lamb daily over the same period. This difference was significant. Andrews *et al.* (1949) obtained almost twice as great a difference as this.

In the second trial, the treated lambs gained 0.37 pound per head daily and the control lambs gained 0.29 pound per head daily, a highly significant difference. It is the opinion of the writer that the slower daily gains made in the second experiment, irrespective of treatment, is due possibly to the fact that the lambs were of poorer quality.

It is of interest to note (table 1), that in spite of the fact that both groups of lambs were offered all of the feed they would clean up, there was little difference in the average daily feed consumption between the control lambs and the stilbestrol treated lambs. This was true in both trials, indicating that the effect of stilbestrol, as shown by increased daily gains in lambs, was not due to increased feed consumption. In both trials there was a marked difference in the feed requirements per hundred pounds of gain in favor of the stilbestrol treated lambs. This is in agreement with the work done with heifers by Dinusson *et al.* (1949) and Andrews *et al.* (1949)

TABLE 1. EFFECT OF STILBESTROL ON GROWTH RATE, FEED CONSUMPTION, FEED EFFICIENCY, AND CARCASS GRADE OF LAMBS

Comparison	Trial I (Feeding period 74 days)		Trial II (Feeding period 92 days)	
	Treated	Controls	Treated	Controls
No. lambs	26	26	25	25
Av. initial wt., lbs.	62	64	69	69
Daily gain/lamb, lbs.	0.43*	0.35	0.37**	0.29
	Av. Daily Feed Consumption (lbs.)			
Shelled corn	1.56	1.46	1.90	1.85
Brome hay	1.17	1.20	1.39	1.40
Soybean oil meal	.15	.14	.19	.19
Total	2.88	2.80	3.48	3.44
	Feed per 100 pounds of gain (lbs.)			
Shelled corn	362	411	501	626
Brome hay	272	339	371	480
Soybean oil meal	36	41	50	65
Total	670	791	922	1169
	No. Carcasses in each Grade***			
U.S. Choice	9	9	1	3**
U.S. Good	5	5	6	19
U.S. Commercial			12	3
U.S. Utility			6	

* Difference was significant ($P < 0.05$).
** Difference was highly significant ($P < 0.01$).
*** Ewe lambs in the first trial were not sold.

with lambs. However, it should be pointed out, that during both trials it appeared to be a little easier to keep the stilbestrol lambs on feed than the control lambs. The treated lambs were very active during both trials and showed no signs of sluggishness. All of the feed fed was charged against the lamb gains and no credit was made for the feed refused. The feed refusal in both trials in both the treated groups and the control groups was almost identical, not only for the entire period but from day to day.

In the first trial, the data on the carcass grade shows that there were the same number of lambs that graded choice and good in both groups. This is not in agreement with the results of the Purdue workers, but it must be remembered that the lambs in this experiment were on full feed while the Purdue workers limited the amount of gain their lambs received. In addition the lambs in the first trial were younger at the time they were treated.

These two facts may have an important bearing on carcass grade. In the second trial, the control lambs had a higher average carcass grade, and when numerical values were assigned to each grade and treated statistically, the differences were highly significant. The carcasses of the treated lambs were quite prominent through the hip region and were soft and watery over the entire carcass. These data would indicate that stilbestrol treatment will increase the daily rate of gain, decrease the feed required per hundred pounds of gain, and have little effect on daily feed consumption. The carcass grade of the lambs treated when they were four months of age was not affected by the treatment. However, lambs treated when seven or eight months of age, were of lower carcass grade than the controls. Whether breed differences, such as slow maturing Rambouillet lambs as compared with early maturing Hampshires or Suffolks, would have a significant effect on the carcass cannot be said at this time.

Summary

The subcutaneous implantation of a 12-milligram pellet of stilbestrol in the neck, at the base of the ear, of either four-month-old feeder lambs or seven to eight-month-old feeder lambs, significantly increased the rate of gain. This increase amounted to an average of .08 pound per lamb daily in both trials. In the first trial, the feed required for each hundred pounds of gain was reduced 16 percent by the treatment with stilbestrol and in the second experiment, lambs treated when they were seven to eight months old required 21 percent less feed for each hundred pounds of gain than the control lambs. There was little or no difference in the daily feed consumption of the treated or control lambs, but the stilbestrol treated lambs were easier to keep on full feed than the controls. There was no significant difference in the carcass grade between the treated and the control lambs of four months of age, but the treated lambs of seven months of age were of a lower grade than the controls.

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PHYSIOLOGICAL EFFECTS OF THIOURACIL AND SIMILAR DRUGS ON SHEEP[1,2]

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THE discovery of thiouracil and its derivatives as potent substances for inhibiting the function of the thyroid gland (Astwood, 1943; Astwood *et al.*, 1945 and McGinty and Bywater, 1945) has made it possible to study some of the effects of limiting thyroid functions. A detailed report indicative of the effects of these substances on the thyroid gland is given by Astwood *et al.* (1943). They reported rapid enlargement of the thyroid glands of rats during the first few weeks of treatment. Microscopic examination showed a marked hyperplasia of the follicular epithelium, a decrease in stored colloid and an increase in vascularity of the glands. The thyroid glands of rats treated for two to six months with a diet containing 2 percent sulfaguanidine or 0.1 percent thiourea in the drinking water still exhibited an orderly cellular arrangement and upon cessation of treatment the glands rapidly regressed toward a normal condition.

Increased blood cholesterol has been associated with thyroidectomy and hypothyroidism of the dog (Schmidt and Hughes, 1938; Thompson and Long, 1941; Entenman, Chaikoff and Reichert, 1942), of infant rhesus monkeys (Fleischmann *et al.*, 1943) and of humans (Hurxthal and Simpson, 1941). Wilkins *et al.* (1941a, 1941b) found serum cholesterol to be higher in hypothyroid than in normal children. No significant trend in serum cholesterol of adult rhesus monkeys occurred as a result of administering thiouracil (Aranow *et al.*, 1946)

Leukopenia and granulocytosis have occurred frequently as a result of administering thiouracil and thiourea to humans and similar findings have been reported with rats by Goldsmith *et al.* (1944) and Williams *et al.* (1944). Hughes (1944) found a slight but statistically significant difference in the hemoglobin levels of thiouracil-treated and control rats.

Levin and Leathem (1942) reported an increase in the serum globulin of rats as a result of thyroidectomy and an increase was also shown by Leathem (1945a) (1945b) as a result of administering thiourea.

Evidence that the thyroid plays a part in the conversion of carotene to

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vitamin A has been indicated by Wendt (1935) and Wohl and Feldman (1939). Clausen and McCoord (1938) reported that in the majority of cases of human hypothyroidism, plasma carotene was high and plasma vitamin A was low.

Little information is reported in the literature relative to the effect of hypothyroidism on blood sugar. Bodansky (1924) reported that there is a tendency for blood sugar to be low. In a review Houssay (1946) points out that it has been shown in severe thyroid deficiency in certain animals and man that fasting blood sugar is usually normal or slightly low. Althousen and Stockholm (1938) reported that dextrose absorption from the intestines was low after thyroidectomy.

The possible use of thiouracil and similar drugs to enhance fattening efficiency of lambs emphasized the importance of studying the physiological effects of these drugs on sheep.

Experimental

The effects of thiouracil, propylthiouracil, thiourea and thyroprotein on the thyroid glands of feeder lambs were studied in seven different experiments from 1945 to 1948.

In three of the experiments (designated experiments I, II and III) the drugs were incorporated in the feed of full-fed western lambs. The details of feeding and management of these animals are presented in previous papers (Andrews *et al.*, 1947; Barrick *et al.*, 1949). The average daily drug intake per animal for the various treatments is shown in table 1. Each of the treatments in Experiments II and III were replicated 4 times except the thyroprotein treatments in Experiment III which were replicated only twice. Thyroid glands were obtained from approximately one-half of the animals in each lot or replication at the time of slaughter.

Four experiments (designated Experiments IV, V, VI, and VII) were conducted in which the drugs were administered individually to feeder lambs in capsule or tablet form. These animals were used for blood studies as well as for studying the effects of the treatments on the thyroid glands. The daily treatments and period of treatment are indicated in the headings of table 2.

With the exception of Experiment IV all the animals were group fed and one-half of the daily drug dosage was administered orally prior to the morning and evening feed with a balling gun. The animals in Experiment V were divided into trios with a member of each trio on each of three treatments. These animals were fed individually and the feed intake was equalized for all members of a trio.

Western feeder lambs were used in Experiments IV, V and VII and pure-

bred Rambouillet, Southdown, Shropshire and crossbred Hampshire × Rambouillet lambs which were obtained from the University Flock were used in Experiment VI.

During the progress of Experiment IV one-half the animals were bled each week for the determination of blood hemoglobin, cholesterol, glucose, leukocyte and erythrocyte counts. Total blood plasma protein, albumin, and globulin analysis were made on each animal three times during the latter part of the experiment. Carotene and vitamin A determinations were made on each animal after 78 days of dry lot feeding and 5 and 9 days after the animals had been permitted to graze green pasture to increase the carotene intake.

Blood studies were made on the trios with equalized food intake (Experiment V). One member of each trio served as a control, one received 1.0 gm. of thiouracil and one received 0.1 gm. of propylthiouracil. Five trios received the above treatment and the drug treatment was doubled for one trio. All animals were bled weekly for cholesterol, carotene and vitamin A determinations and during each two-week period for determination of total protein, albumin, globulin and fibrinogen.

In Experiment VII frequent checks were made of the blood plasma cholesterol values for each animal and the carotene and vitamin A content were checked 4 times during the progress of the experiment.

During the latter part of Experiment I a check was made on $\frac{1}{3}$ or more of the lambs on each treatment for blood hemoglobin, leukocyte counts and blood plasma vitamin A levels. Blood plasma cholesterol was determined on $\frac{1}{2}$ of the lambs and blood plasma vitamin A on approximately $\frac{1}{3}$ of the lambs on each treatment of the latter part of Experiment III.

Blood for analysis was drawn from the jugular vein into oxalated tubes, placed in an ice water bath and taken immediately to the laboratory for analysis. Hemoglobin was determined by the method of Evelyn (1936), cholesterol by a modification of the method of Pjoan and Walter (1937), blood sugar by a modification of Folin's micro-method (1928), total protein, albumin, globulin and fibrinogen by a modification of the method given by Hawks and Bergeim (1937), and vitamin A by a modification of Kimble's procedure (1935). Tissues were fixed at the time of slaughter and prepared for microscopic examination. Erythrocyte counts were made by standard procedures using hemocytometer counting chambers.

Results and Discussion

Thyroid Size and Histology

The effect on gross thyroid weight of administering the drugs (thiouracil, propylthiouracil, thiourea and thyroprotein) with the feed are shown in

table 1. The data for Experiment I show that all levels of thiouracil (0.18 to 1.15 gm. per lamb per day) and thiourea (0.05 to 0.07 gm. per lamb per day) caused significant increases ($P < 0.01$) in the average gross thyroid weight. The planned intake of thiourea was $\frac{1}{4}$ gm., $\frac{1}{2}$ gm. and 1 gm. per lamb per day for the three treatments but this intake could not be approached due

TABLE 1. EFFECT OF THIOURACIL, PROPYLTHIOURACIL, THIOUREA AND THYROPROTEIN ON THYROID WEIGHTS OF LAMBS (DRUGS INCORPORATED IN THE FEED)

Experiment I. Winter 1945–46 (Treatment 84 days)

Treatment	Control	0.18 gm. thiouracil	0.33 gm. thiouracil	0.54 gm. thiouracil	1.15 gm. thiouracil	0.07 gm. thiourea	0.05 gm. thiourea	0.06 gm. thiourea
No. of glands weighed	10	10	10	10	10	10	10	10
Average wt., gm.[1]	2.30	12.18	10.53	13.58	9.78	7.56	11.93	14.60

Experiment II. Winter 1946–47 (Treatment 115 days)

Treatment	Control	0.21 gm. thiouracil	0.39 gm. thiouracil	0.03 gm. propyl-thiouracil				
No. of glands weighed	20	20	20	20				
Average wt., gm.[1]	3.83	3.22	2.64	2.76				

Experiment III. Winter 1947–48 (Treatment 42–84–126 days)[2]

Treatment	Control	0.42 gm. thiouracil	0.63 gm. thiouracil	0.52 gm. thyro-protein	1.04 gm. thyro-protein			
No. of glands weighed	34	36	33	17	18			
Average wt., gm.[1]	3.21	2.83	2.78	4.01	3.37			

[1] Least significant mean differences:

Experiment	5% level	1% level
I	3.77 gm.	5.01 gm.
II	0.49 gm.	0.65 gm.
III	0.78 gm.	1.03 gm.

[2] Size of the thyroid did not vary as a result of period of treatment.

to the refusal of the protein pellets containing thiourea by the lambs. The protein pellets containing thiouracil were not consumed in the quantities planned which would have given a thiouracil intake of $\frac{1}{4}$ gm., $\frac{1}{2}$ gm., 1 gm. and 2 gm.

The thyroid glands of the lambs which received either thiourea or thiouracil in this experiment showed clear cut and rather uniform evidence of stimulation. Of the 69 glands of treated animals examined microscopically

only three were not classified as hyperplastic, and the follicular epithelium of the three was definitely hypertrophic. In most of the treated animals examined the thyroid follicles were made up of tall columnar epithelial cells which were usually present in increased numbers. The follicles were frequently irregular in form because of the extreme hyperplasia and usually contained little if any colloid. Numerous small follicles in which the lumen was very much reduced in size were seen and in about 20 percent of the glands the follicular epithelium appeared to be disorganized. There was no marked histological difference between either the thiouracil or thiourea lots or between the animals receiving different amounts of these drugs.

The thyroid glands of the control animals were not entirely normal. Two of the 10 control glands were classified as hyperplastic, and columnar epithelium was observed in four. However, the thyroids of the control animals were grossly and microscopically different from those of the treated lambs. Five glands were classified as normal and all but two had large quantities of stored colloid.

The administration of thiouracil and propylthiouracil did not cause any increase in thyroid size or measurable histological changes in Experiment II in the winter of 1946–47. In these trials thyroid weight was greatest, although normal, in control lambs (table 1) An analysis of the data showed that the sheep which received 0.4 gm. of thiouracil or 0.03 gm. of propylthiouracil daily had significantly smaller thyroids than the controls ($P < 0.01$). The thyroids of the lambs which received 0.2 gm. of thiouracil were significantly heavier than those of lambs which received 0.4 gm. of thiouracil ($P < 0.05$), and significantly lighter than the controls ($P < 0.05$).

Microscopic examination of the thyroids of $\frac{1}{2}$ the lambs from each lot did not reveal any evidence of stimulation as a result of treatment. The thyroids of the control group and a few of the thyroids from the treated groups showed hyperplasia with some hypertrophy, but the degree of stimulation was not comparable to that observed in 1945–46. Large amounts of stored colloid were present in many glands from the treated groups. It must be concluded that the thyroid histology was not significantly altered by treatment in 1946–47.

In Experiment III conducted in the winter of 1947–48 the effect of thiouracil on the thyroid glands tended to be similar to that observed the previous year. The thyroid glands of animals receiving 0.4 gm. and 0.6 gm. of thiouracil were lighter than those of the controls. This difference was not statistically significant, however. The thyroids of the lambs receiving 0.5 gm. of thyroprotein were significantly heavier ($P < 0.01$) than those from the lambs which received thiouracil and also heavier than those from the control lambs ($P < 0.05$). The glands from the lambs which received 1.0

TABLE 2. EFFECT OF THIOURACIL, PROPYLTHIOURACIL AND THIOUREA ON THYROID WEIGHTS OF LAMBS (DRUGS ADMINISTERED IN CAPSULES OR TABLETS)

Experiment IV. Summer 1946 (Treatment 86 days).

Treatment	Control	½ gm. thiouracil	1.0 gm. thiouracil	3.0 gm. thiouracil
No. of glands weighed	6	6	6	6
Average wt., gm.	14.20	18.90	14.32	11.51

Experiment V. Winter 1946-47 (Treatment 77 days)

Treatment	Control	1.0 gm. thiouracil	0.1 gm. propyl-thiouracil	
Individual gland weights, gm.	2.10 2.00 2.25	1.35 1.70 2.60	2.50 2.70 1.75	

Experiment VI. Summer 1947 (Treatment 77 days)

Treatment	Control	½ gm. thiouracil	1.0 gm. thiouracil	
Individual gland weights, gm.	4.20 2.26	5.50 2.24 3.10	4.65 3.10 2.90	

Experiment VII. Winter 1947-48

Treatment	Control	1.5 gm. thiouracil	3.0 gm. thiouracil	1.0 gm. thiourea
No. of days on experiment and individual gland weights, gm.	110-4.25 110-2.32	27-3.04 110-3.35 110-3.56	27- 5.68 103-7.70 110-16.93	22- 4.05 105-22.05

gm. of thyroprotein were somewhat heavier than those from the thiouracil treated lambs although this difference was not statistically significant.

Histologically there were no obvious differences in the thyroid glands from the control and the thiouracil-treated animals. The glands from the lambs which received thyroprotein, however, were different; all contained low cuboidal or nearly flat epithelial cells, an abundance of colloid and were in an inactive or resting state in most instances. As in the previous experiment the thyroid glands from the control animals were not all normal histo-

logically and showed some evidences of stimulation. About one-half of the glands of the controls showed epithelial hypertrophy and about one-third of the glands showed hyperplasia. Iodized salt was fed to one-half of the lambs on each treatment and this did not influence the size or histology of the thyroid glands.

Thiouracil administered in capsule or tablet form at the rate of $\frac{1}{3}$ gm. to 1.5 gm. per lamb daily (Experiments IV, V, VI, and VII) did not increase thyroid weight (table 2) nor produce histological changes different from those observed in the control animals.

The control thyroids as well as those treated with thiouracil were enlarged in Experiment IV. These animals were from the same original group as those used in Experiment I and were approximately 4 months older at the time of slaughter. The average thyroid weight of the control lambs in Experiment I was only 2.30 gm. whereas it was 14.20 gm. for similar control animals in Experiment IV. It is possible that this increase in size was a result of borderline iodine deficiency. The lambs were wintered on a farm where iodine deficiency had previously occurred. The thyroid glands from the sheep which received 1 gm. and 3 gm. of thiouracil daily showed more histological evidence of stimulation than those from the control animals although this difference was not marked and the difference in gross thyroid weight was not significant.

The data in table 2 for Experiment V show that neither 1 gm. of thiouracil nor 0.1 gm. of propylthiouracil per lamb daily affected the gross thyroid weight. No pronounced differences in the glands were observed when they were examined microscopically. Nine additional animals handled as trios and treated the same as those in Experiment V were continued on increased levels of thiouracil and propylthiouracil for various periods of time. Treatment for 3 weeks with either 3 gm. of the thiouracil or 1 gm. of propylthiouracil resulted in increased size of the gland and marked hyperplasia. Two gm. of thiouracil administered for the same period did not produce such definite changes in the thyroid glands.

In the summer of 1947 four- to five-month-old lambs from the Purdue University Flocks did not show pronounced effects from the administration of $\frac{1}{3}$ gm. or 1 gm. of thiouracil (table 2 Experiment VI). The thyroids from these lambs all showed some hypertrophy and hyperplasia which was most marked in the case of those of Rambouillet breeding.

In Experiment VII treatment with 3 gm. of thiouracil or 1 gm. of thiourea caused marked changes in the thyroid. Histological changes were evident at the earliest period of examination, 22 days for the thiourea treated lambs, and 27 days for those receiving 3 gm. of thiouracil. The follicular epithelium

was taller in the glands from the lambs that received 1.5 gm. of thiouracil than on the controls even though the gross weight was not greater.

The reasons for the marked effects of small intakes of thiouracil on the thyroid glands in Experiment I and not in subsequent experiments have not been determined. It seems possible that the goitrogenic effect of the drug used in this experiment was much greater than that used thereafter. Variation in the experimental animals offers the only other explanation for the results obtained. The possibility of the drugs exhibiting a greater effect as a result of borderline iodine deficiency of the animals cannot be overlooked. The thyroids from the control lambs were not enlarged although some of them were not typically normal.

With the exception of Experiment I these data indicate that approximately 3 gm. of thiouracil per lamb daily are required to cause marked effects on the thyroid gland of western feeder lambs. This is roughly 0.2 percent of the ration and is in the range of levels that have been reported to be effective with the rat, chicken and hog. Thiourea had a more pronounced goitrogenic effect on sheep than thiouracil. Results of these experiments indicated it was at least three times as effective as thiouracil. Although effective levels of propylthiouracil were used on only two animals, indications were that it was also more effective per unit weight for sheep than thiouracil.

Components of the Blood

Cholesterol. The administration of 1 to 3 gm. of thiouracil to feeder lambs resulted in most instances in increased blood plasma cholesterol. Treatment with 1 or 3 gm. of thiouracil per sheep daily in Experiment IV caused a highly significant increase in the blood plasma cholesterol, however ½ gm. of thiouracil did not cause a marked effect (table 3). The average values show that blood cholesterol increased about 30 percent above pretreatment values.

In Experiment V the first drugs were administered to four of the trios on February 3. These same animals were shorn later. The other two trios were started on treatment February 27, and the animals in one of these trios received twice the daily drug dosage of the other trios in the experiment. Average cholesterol values for the animals started on treatment February 3, are shown in table 4. It will be noted that under the conditions of this experiment, cholesterol values for the animals receiving 1 gm. of thiouracil were higher than the controls for the first two weeks of treatment only. The differences were highly significant the first week ($P < 0.01$) and significant for the second week ($P < 0.05$). Much of the increase shown for the second week was due to one animal which had eaten only four pounds of feed for the

TABLE 3. EFFECT OF THIOURACIL, THIOUREA AND THYROPROTEIN ON CHOLESTEROL IN BLOOD PLASMA OF SHEEP

Results expressed in mg. per 100 ml.

Experiment IV. Summer 1946

Treatment	Control	½ gm. thiouracil	1.0 gm. thiouracil	3.0 gm. thiouracil
Number of Animals	6	6	6	6
Before treatment	58	55	58	64
1st period[2]	54	55	75**	82**
2nd period	56	62	82**	86**
3rd period	65	63	79**	87**
4th period	53	55	79**	79**
5th period	55	53	73**	82**
Average (5 periods of treatment)	57	58	78**	82**

Experiment VII. Winter 1947–48

Treatment	Control	1.5 gm. thiouracil	3.0 gm. thiouracil	1.0 gm. thiourea
Number of Animals	2	2	2	2
24 November	54	51	51	58
4 December[1]	64	66	55	62
19 December	58	76**	83**	132**
26 January	54	61	90**	46
2 February	50	80**	95**	60
11 February	60	87**	88**	74**
10 March	71	87**	87**	108**

Experiment III. Winter 1947–48

Treatment	Control	0.42 gm. thiouracil	0.63 gm. thiouracil	0.52 gm. thyroprotein	1.04 gm. thyroprotein
Number of Animals Checked	23	24	23	11	12
Mg. Cholesterol per 100 ml.	60	63	76**	59	61

** Significant increase 1 percent level.

[1] Thiouracil started December 4—Thiourea started December 9.

[2] Period represents two weeks.

week and lost three pounds in weight. It is believed that the increase for this animal was not entirely attributable to the thiouracil, but that an increase in cholesterol was associated with the utilization of stored body lipids. The high cholesterol value for the thiouracil-fed lambs for March 12

can be attributed primarily to one animal with a high value which showed a weight loss for that week. It is believed that the increase in cholesterol values for all lots starting the week of March 19, can be attributed to the effects of shearing (the animals were shorn March 11). The weather was cold during most of the remainder of March and the animals shivered much

TABLE 4. EFFECT OF THIOURACIL AND PROPYLTHIOURACIL ON CHOLESTEROL IN BLOOD PLASMA OF LAMBS. PAIRED TECHNIQUE APPLIED TO TRIOS

Results expressed in mg. per 100 ml.

Experiment V. Winter 1946–47

Treatment	Control	1.0 gm. thiouracil	0.1 gm. propylthiouracil
Number of Animals	4	4	4
Before treatment	58	57	57
11 February	58	83**	56
18 February	61	93*	58
26 February	68	70	55
4 March	60	61	59
12 March[1]	64	82	67
19 March	84	69	86
25 March	75	73	72
1 April	63	65	57
8 April	54	58	59
15 April	69	68	64
22 April	60	67	65

Experiment V_A. Winter 1946–47

Treatment	Control	2.0 gm. thiouracil	0.2 gm. propylthiouracil
Number of Animals	1	1	1
Before treatment	58	62	62
4 March	53	64	54
12 March	62	95	52
19 March	57	92	69
25 March	55	95	52
1 April	55	84	54
8 April	62	76	48
15 April	52	78	50
22 April	55	83	63

* Significant 5 percent level.
** Significant 1 percent level.
[1] Animals shorn March 11.

of the time. Many of the animals lost weight on the two successive weeks following shearing.

Table 4 (Experiment V_A) shows the effect on one of the trios of doubling the dosage of the drug. These animals were not shorn so this additional variable does not interfere with the data obtained. In this one instance 2 gms. of thiouracil were effective in maintaining the cholesterol at an increased level. The increased dosage of propylthiouracil had no noticeable effect on the cholesterol values. In a second trio that was not shorn but received only 1 gm. of thiouracil or 0.1 gm. of propylthiouracil a significant increase in cholesterol occurred in the lamb receiving thiouracil for the second week of treatment only.

Cholesterol values were not checked routinely in Experiment VII. However, the results in table 3 show that treatment with 1.5 and 3 gm. of thiouracil and 1 gm. of thiourea caused a significant increase in blood cholesterol over the control lambs ($P < 0.01$). The erratic fluctuation of the values reported for the thiourea treated lambs is believed to be associated with the effects the drug had on feed consumption and weight loss. The lambs went off feed and lost an average of eleven pounds per lamb during the first two weeks of treatment. Following this loss they made very little gain the next 90 days. The increase in cholesterol during periods of weight loss is in agreement with that observed in Experiment V. However, it is not in agreement with the work of Entenman, Chaikoff and Reichert (1942), which showed that the rise in cholesterol of thyroidectomized dogs could be prevented by fasting or by limitation of the caloric intake.

The blood cholesterol level of several lambs selected at random on each treatment the latter part of the feeding period of Experiment III showed a significantly higher blood cholesterol level ($P < 0.01$) for the lambs receiving 0.63 gm. of thiouracil daily in the feed than for the controls, those receiving 0.42 gm. of thiouracil or those receiving thyroprotein (table 3).

Vitamin A and Carotene. A check of several animals on each treatment during the latter part of Experiment I and III showed that the average blood plasma vitamin A level did not vary as a result of the treatments (0.18 to 1.15 gm. of thiouracil, 0.05 to 0.07 gm. of thiourea and 0.5 to 1.0 gm. of thyroprotein). Similarly, blood plasma vitamin A levels of thiouracil-treated lambs in Experiment IV did not differ significantly from control animals after 75 days on dry feed. However, when the carotene intake was increased by permitting the animals to graze on green pasture the blood plasma vitamin A of the controls was significantly higher than for animals receiving $\frac{1}{3}$ gm., 1 gm., and 3 gm. of thiouracil (table 5). The blood plasma carotene content tended to be higher in the thiouracil-treated than in the control animals as shown in the table. Blood plasma vitamin A levels did not vary as a result

TABLE 5. EFFECT OF THIOURACIL ON VITAMIN A AND CAROTENE IN BLOOD PLASMA OF SHEEP

Results expressed in micrograms per 100 ml.

Experiment IV. Summer 1946

Treatment	Control	½ gm. thiouracil	1.0 gm. thiouracil	3.0 gm. thiouracil
No. of Animals	6	6	6	6
Vitamin A				
29 June	21	21	20	17
5 July	37	27**	27**	26**
9 July	37	31**	30**	25**
Carotene				
29 June[1]	4	4	7	5
5 July	8	13	11	15
9 July	10	10	18	13

Experiment V. Winter 1946–47

Treatment	Control	1.0 gm. thiouracil	0.1 gm. propylthiouracil
No. of Animals	6	6	6
Vitamin A[2]			
Before treatment	35	32	35
1st period, 4 weeks	29	26	26
2nd period, 4 weeks	30	25	30
3rd period, 3 weeks	33	32	33

Experiment VII. Winter 1947–48

Treatment	Control	1.5 gm. thiouracil	3.0 gm. thiouracil	1.0 gm. thiourea
No. of Animals	2	2	2	2
Vitamin A				
4 December[3]	27	28	25	24
26 January	26	27	23	14
11 February	29	30	25	19
10 March	29	31	26	15

** Significantly less than controls ($P < 0.01$).

[1] Animals in dry lot through June 30th. Green pasture thereafter.

[2] Each value represents 4 determinations on successive weeks for each animal except for the third period which is represented by 3 determinations.

[3] Thiouracil treatment started December 4th. Thiourea treatment started December 9th.

of administering 1.0 gm. of thiouracil or 0.1 gm. of propylthiouracil when the feed intake was controlled for animals on the different treatments (table 5, Experiment V). The blood plasma carotene content for all treatments was low and did not vary significantly. The carotene intake in this experiment was undoubtedly much lower than was obtained with the lambs on pasture in Experiment IV.

In Experiment VII thiouracil treatment did not alter the blood plasma vitamin A level; however, 1.0 gm. of thiourea caused a marked drop in two lambs studied. This drop had occurred when the first check was made 7 weeks after the beginning of treatment and the low level was maintained for the duration of the experiment. The fact that the feed intake of the thiourea-treated lambs dropped off markedly with the initiation of treatment, and was only sufficient to maintain body weight for most of the experiment, may have been responsible for this lower blood plasma vitamin A level. There was no significant amount of carotene in the blood plasma of any of the lambs on the dates tested.

Although there is evidence in the literature that hypothyroidism is associated with reduced ability to convert carotene to vitamin A (Fasold and Heidemann, 1933–34; and Wohl and Feldman, 1939) the extent of the hypothyroidism produced in feeder lambs by thiouracil in these experiments did not interfere sufficiently to influence the blood plasma carotene or vitamin A while the animals were being fed in dry lot. The fact that the carotene content of the blood was very low even when the animals were on a high carotene intake indicates that there was no serious interference with their ability to convert carotene to vitamin A.

Blood Plasma Proteins. Determinations for total protein, albumin and globulin in the blood plasma were made during the latter part of Experiment IV. An average of 3 analyses showed a significantly higher globulin level ($P < 0.01$) in the blood plasma of the lambs receiving 1 and 3 gm. of thiouracil than in control lambs. However, no pretreatment values were available for comparison.

Total protein, albumin, globulin and fibrinogen were determined on each of the 18 animals in Experiment V on 3 successive weeks prior to initiation of treatment and approximately every two weeks during the experiment. Table 6 shows the results of the analyses. The pretreatment values and those for the first six-week period are averages of 3 determinations on each lamb and those for the second four-week period are averages of 2 determinations on each lamb. Neither thiouracil at the rate of 1 gm. nor propylthiouracil at the rate of 0.1 gm. per lamb daily caused any significant variation in the different protein fractions. Although the serum globulin did not increase in the thiouracil treated lambs as reported for thiourea-fed rats by Leathem

TABLE 6. EFFECT OF THIOURACIL AND PROPYLTHIOURACIL ON BLOOD PLASMA PROTEINS OF LAMBS

Experiment V

Results expressed in gms. of protein per 100 ml.[1]

Treatment	Control	1.0 gm. thiouracil daily	0.1 gm. propylthiouracil daily
No. of animals	6	6	6
Total Protein			
Before treatment	6.21	6.23	6.33
1st period, 6 weeks	6.09	6.11	6.04
2nd period, 4 weeks	6.23	6.18	6.12
Albumin			
Before treatment	3.88	4.05	3.95
1st period, 6 weeks	3.86	3.94	3.84
2nd period, 4 weeks	4.07	4.06	4.15
Globulin			
Before treatment	2.11	1.99	2.16
1st period, 6 weeks	2.01	1.96	2.00
2nd period, 4 weeks	1.77	1.89	1.75
Fibrinogen			
Before treatment	.219	.196	.218
1st period, 6 weeks	.216	.211	.197
2nd period, 4 weeks	.221	.227	.224

[1] Each value represents an average of 3 determinations on each animal at approximately 2 week intervals except the values for the 2nd period which are represented by 2 determinations on each animal. Differences are not statistically significant.

(1945a) it is possible that the level of thiouracil was not high enough to be effective.

Blood Sugar. Examination of the blood sugar content of thiouracil-treated sheep (Experiment IV) at two-week intervals for a period of 10 weeks did not show any significant changes as compared with pretreatment values or with the control animals. Average values for the last four weeks of treatment expressed in mg. of blood sugar per 100 ml. of blood were 72, 69, 70, and 67 for the controls, and those receiving $\frac{1}{3}$ gm., 1 gm. and 3 gms. of thiouracil per day, respectively.

Hemoglobin, Erythrocyte Counts and Leukocyte Counts. A spot check was made on a limited number of lambs administered thiouracil and thiourea in

the feed at the close of Experiment I and periodic checks were made of the sheep administered thiouracil in capsules (Experiment IV) for blood hemoglobin, erythrocyte counts and leukocyte counts. The results showed that these blood components were not affected by thiouracil intakes of 0.18 to 3.0 gms. and thiourea intakes of 0.05 to 0.07 gm. per lamb daily for periods of approximately 12 weeks.

Summary and Conclusions

Thiouracil administered in the feed of feeder lambs at levels below one gram per lamb per day resulted in marked stimulation of the thyroid glands in only one of three years experiments. In this one experiment the thyroids from lambs receiving as little as 0.18 gm. of thiouracil per lamb daily were 5 times heavier than the glands from control animals and showed marked histological evidence of stimulation. Thiourea also caused marked stimulation of the thyroid glands. In two of the experiments the thyroids from lambs receiving 0.2 to 0.6 gm. of thiouracil per day were smaller than the thyroids from control lambs and histologically the glands from treated animals were very similar to those from the controls.

Thyroid glands from lambs administered 0.5 gm. and 1.0 gm. of thyroprotein per head daily in the feed were larger than the thyroids from controls and thiouracil treated lambs. Histologically the thyroids from the thyroprotein treated lambs were easily detected by the very low or flat follicular epithelium and the general appearance of inactivity.

Thiouracil administered orally in capsule or tablet form to feeder lambs at levels up to 1.5 gm. per lamb per day for 110 days exhibited very little goitrogenic effect. However, the effect was evident at a level of 3 gm. per day. The glands were enlarged and showed histological evidence of stimulation.

The oral administration of 1 gm. of thiourea per lamb daily in tablet form caused marked stimulation of the thyroid gland and seriously limited feed consumption and rate of growth.

Propylthiouracil administered orally at the rate of 0.1 gm. per day in tablet form did not affect the thyroid gland significantly; however, marked evidence of stimulation resulted from the administration of 1.0 gm. of propylthiouracil for three weeks.

Blood plasma cholesterol was increased approximately 30 to 40 percent as a result of administering thiouracil and thiourea to feeder lambs. This increase was quite generally obtained on thiouracil intakes of 1 to 3 gm. per day and was noted in a group of fattening lambs receiving 0.6 gm. of thiouracil in the feed.

A marked increase in blood plasma cholesterol was noted in lambs losing weight regardless of thiouracil treatment.

Vitamin A levels in the blood plasma of lambs fed in dry lot were not affected by thiouracil. However, in one experiment in which lambs treated with thiouracil were permitted to graze on green pasture following a dry lot feeding period, the increase in blood plasma vitamin A levels was significantly less than the increase which occurred in control lambs.

Total protein, albumin, globulin and fibrinogen in the blood plasma were not significantly affected by 1 gm. of thiouracil or 0.1 gm. of propylthiouracil in lambs on controlled feed intake.

Blood hemoglobin, erythrocyte counts and leukocyte counts were not affected by thiouracil intakes up to 3 gm. per lamb daily.

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A STUDY OF THE FUNCTION OF COBALT IN THE NUTRITION OF SHEEP[1]

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THE essentiality of cobalt in the diet of sheep has been proved by Underwood and Filmer (1935), Marston *et al.* (1938), Bowstead and Sackville (1939), Bowstead *et al.* (1942), Pope *et al.* (1947), and by Keener *et al.* (1948). Numerous workers in this country and abroad also have identified cobalt deficiency in cattle. Little progress appears to have been made, however, in determining the function of cobalt in the diet of ruminants until Rickes *et al.* (1948) isolated vitamin B_{12} and found that it was a cobalt complex. Although the role of cobalt in vitamin B_{12} synthesis may not be the one which is involved in cobalt deficiency, this discovery apparently marks an important advance in determining the overall function of cobalt in animal nutrition.

It is believed generally that cobalt has an essential function in the production of some sort of appetite-stimulating factor by the flora of the rumen. The principal reasons for this are that cobalt deficiency has been found only in ruminants and that, as reported by McCance and Widdowson (1944), injected cobalt, unlike that administered orally, has not been effective in relieving the deficiency. Ray *et al.* (1947) reported that the concentrations of both nicotinic acid and the vitamin B_6 group were lower in the blood of cobalt deficient sheep than in that of normal sheep. There was a suggestion of a similar lowering of riboflavin, but the levels of folic acid and pantothenic acid were not affected. Ray *et al.* (1948) reported that the oral administration of cobalt salts to cobalt deficient sheep brought about a rapid increase in appetite and body weight, but that the injection of cobalt salts gave a slower response. Thiamin injections also were reported to have brought about a definite improvement in rate of body gain and in appetite.

If cobalt deficiency is to be eliminated completely as a problem in the

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feeding of ruminants, it is essential that the nutritional role of this element be understood. The experiment reported here was carried out in an attempt to gain a better understanding of this role.

Experimental Procedure

Locally obtained yearling ewe and wether lambs were used as experimental subjects. All were healthy, purebred animals from well-kept flocks. As far as was known, cobalt deficiency had not been observed on any of the farms from which the lambs were obtained. From the thirty lambs obtained for the experiment, ten pairs were selected on the basis of breed, sex, and weight. One member of each pair was given supplemental cobalt. The other member of each pair and ten additional animals were fed only the basal ration until after marked cobalt deficiency symptoms had developed. At this time the deficient animals were consuming approximately one-fourth the normal amount of feed, they had lost considerable body weight, and their physical condition was generally poor. When each animal reached this stage of deficiency, it was given one of the treatments listed in table 2.

The roughage fed to all lambs was a locally grown grass hay of average quality. It contained 0.07 p.p.m. of cobalt. The principal concentrate mixture fed consisted of nine parts of ground corn and one part of non-fat dry milk solids. The corn, which was grown in North Carolina, contained only 0.01 p.p.m. of cobalt. To see if certain B complex vitamins and high quality protein in the milk solids might delay the onset of cobalt deficiency, three pairs of lambs were fed only the low-cobalt corn as the concentrate for 50 weeks. Since differences in response to diet failed to appear, these animals were changed to the regular concentrate mixture. Because the experiment was continued over a longer period than was originally planned, it was necessary to feed locally purchased corn meal to the ten cobalt supplemented animals during the last 18 weeks of the experiment in order to have adequate low-cobalt corn for the other animals.

The lambs were maintained in individual pens throughout the experiment. Hay was fed according to appetite, while concentrates were limited to one pound a day. Water was kept before the animals in glazed earthen jars at all times except during freezing weather when it was offered twice a day. A plain salt brick was kept before each animal. Cobalt sulfate was administered to each of the ten cobalt supplemented animals at the rate of 3.5 mg. of cobalt twice per week as a drench. The lambs were treated for internal parasites before the start of the experiment and during the experiment as examination of the feces indicated.

After a preliminary period during which the animals were paired, the experiment was started on March 3, 1947. The last animals were removed from the experiment on June 21, 1948.

Experimental Results and Discussion

The results of this experiment substantiate previous work of Keener *et al.* (1948) which showed that cobalt deficiency could be developed when sheep were fed a low-cobalt native grass hay and corn. The first symptom of cobalt deficiency observed was a decrease in feed consumption. The average length of time required for this symptom to become evident in all of the sheep fed the basal ration was 23.9 weeks. The average time to the first treatment was 44.9 weeks. There was considerable variation in the time required for the earliest deficiency symptoms to appear. There was an even greater variation in the time required for severe cobalt deficiency to become evident. The effects of cobalt deficiency on feed and water consumption and on body

TABLE 1. EXPERIMENTAL GROUPS AND SUMMARY OF PRETREATMENT CHANGES

Diets	Groups	Number of sheep	Initial weights, lbs.	Time to first def. symptoms, wks.	Time to initiation of treatments, wks.	Pre-treatment gains and consumption, lbs.			
						Total gains in weight	Average daily consumption		
							Concentrate	Hay	Water
Basal plus cobalt	Paired	9	73.7			49.9	1.0	1.7	4.4
Basal	Paired	9[1]	73.7	24.4	51.8	7.3	0.2	0.3	2.0
Basal	Unpaired	9[1]	77.2	23.3	38.1	3.3	0.3	0.6	2.2

[1] One animal died in each basal group early in experiment leaving number shown. Reason for deaths is not known

weight are shown in table 1. When only the paired animals are considered, the average increase in body weight for those animals which had received cobalt was nearly seven times that of the non-cobalt animals. The average concentrate consumption of the animals fed cobalt was nearly five times that of the deficient animals, the average hay consumption nearly six times, and the average water consumption over twice. All of these differences are statistically significant at the one percent level. That cobalt deficiency resulted in a marked decrease in feed consumption is very evident. The adverse effect of the deficiency on body weight, however, appears to have been due mainly to an inadequate nutrient intake, not to a direct effect of the deficiency. Similar effects would be expected from limiting the nutrient intake of normal sheep to the amount consumed by the cobalt deficient animals.

It should be noted that every animal fed the basal ration showed severe deficiency symptoms at least once during the experiment, but that none of the cobalt supplemented animals showed any abnormal condition except for a few mild cases of internal parasite infestation which were quickly corrected.

No animal recovered spontaneously from the deficiency. Several animals were permitted to become deficient again after the first deficiency had been corrected by the feeding or the injection of cobalt. These animals were then given some other treatment. When a particular treatment did not bring about any response another treatment was not started for a few weeks, unless the animal was in a very weakened condition. This delay was for the purpose of eliminating as much as possible any residual effects from the previous treatment.

Because symptoms of cobalt deficiency were not evident during the first few months of the experiment, deleterious effects on the wool were not observed in 1947. In 1948, however, the fleeces of almost all of the animals which had suffered from cobalt deficiency were affected. The effects included light weight fleeces, weak places in the wool fibers, and loss of wool. As far as can be determined the weak places were due to a state of undernutrition resulting from the deficiency and not to the deficiency directly. These weak places frequently caused the wool to peel from the skin or to break off uniformly some distance from the body from normal wool which had grown during a subsequent recovery period. In 1948, the average weight of the fleeces from the cobalt deficient animals was 2.9 lbs. lighter than the average weight of those from the cobalt supplemented animals. This difference was significant at the one percent level. Part of this difference was caused by the poor growth of the wool, the remainder to an actual loss of wool.

A summary of the various treatments used in further exploration of the role of cobalt in the nutrition of ruminants is given in table 2. It can be seen that cobalt sulfate when given orally relieved the deficiency in every case. The first response observed was a marked increase in feed consumption. The physical condition of the animals then gradually returned to normal. The length of time from the first treatment to the first indication of response depended more, in general, on the individuality of the animal than on the amount of cobalt fed or the severity of the deficiency. The individuality of the animal also seemed to be a very important factor in determining the speed of recovery. Most animals seemed to recover their appetite for concentrates much more rapidly than for hay.

Intravenous injections of cobalt sulfate also brought about recovery when administered daily or in large amounts twice weekly, but the first indications of response were, in general, considerably slower in appearing than when the cobalt was administered orally. Two animals which received small injections twice a week did not show any improvement. While certain results of Comar *et al.* (1946) indicate that injected cobalt does not reach the rumen contents, other results of Comar and Davis (1947) as well as unpublished

TABLE 2. TREATMENTS ADMINISTERED TO COBALT DEFICIENT SHEEP AND THE RESPONSES OBTAINED

Substances administered	Methods of administration	Amounts given	Frequency of administration	No. of sheep	Ave. duration of treatment	Result of treatment	Ave. time for first response
					weeks		days
Cobalt sulfate	Orally	1 mg.	Daily	2	3.5	Recovery	6.5
		2 mg.	Daily	1	2.0	Recovery	4.0
		3.5 mg.	Twice per week	3	3.3	Recovery	4.3
		7 mg.	Twice per week	3	3.3	Recovery	7.6
		50 mg.	Twice per week	1	4.0	Recovery	7.0
		100 mg.	Once	1	—	Recovery	4.0
	Intravenously	2 mg.	Daily	1	4.0	Slow recovery	11.0
		4 mg.	Daily	1	4.0	Slow recovery	11.0
		6 mg.	Daily	1	4.0	Slow recovery	11.0
		3.5 mg.	Twice per week	1	4.0	Negative	—
		7 mg.	Twice per week	1	4.0	Negative	—
		10.5 mg.	Twice per week	1	4.0	Slow recovery	20.0
Cobalt carbonate	Orally	3.5 mg.	Twice per week	2	4.0	Recovery	9.5
		7 mg.	Twice per week	2	4.0	Recovery	7.5
		50 mg.	Twice per week	2	4.0	Recovery	3.5
Mineral mixture	Orally	700 mg. Mn 350 mg. Fe 87.5 mg. Cu 70 mg. Sn 70 mg. Zn 3.5 mg. Ni	Twice per week	1	.5	Death	
				2	3.5	Negative	

B-complex vitamins	Orally Intravenously in saline	1.5 g. nicotinic acid 100 mg. riboflavin 300 mg. thiamin 50 mg. pyridoxine 50 mg. Ca pantothenate	Concurrently every other day	1	4.0	Negative	
	Orally	500 mg. nicotinic acid 100 mg. thiamin 100 mg. riboflavin 100 mg. Ca pantothenate 30 mg. pyridoxine	Twice per week	1	4.0	Negative	
	Intravenously in saline	200 mg. thiamin 100 mg. pyridoxine 100 mg. Ca pantothenate	Twice per week	1	4.0	Negative	
	Orally	1 g. Parvo (3% folic acid)	Daily	1	3.5	Negative	
	Intramuscularly	4.55 mg. thiamin	Twice per week	3	6.5	Negative	
	Orally	(Mixture A) 8 g. choline chloride 800 mg. inositol 360 mg. nicotinic acid 200 mg. Ca pantothenate 96 mg. p aminobenzoic acid 80 mg. pyridoxine 40 mg. thiamin 40 mg. riboflavin 4 mg. folic acid 0.04 mg. biotin	Daily	2	3.0	Negative	

TABLE 2—(*continued*)

Substances administered	Methods of administration	Amounts given	Frequency of administration	No. of sheep	Ave. duration of treatment	Result of treatment	Ave. time for first response
					weeks		days
B-complex vitamins + Ascorbic acid + Amino acids	Orally	B complex vitamins (Mixture A above) 1 g. ascorbic acid 2 g. methionine 1 g. tryptophane	Daily	1	4.0	Negative	
B-complex vitamins + Liver extract	Orally Subcutaneously	B complex vitamins (Mixture A above) 2.5 ml. liver extract	Daily	1	3.0	Negative	
Liver extract	Subcutaneously	2.5 ml.	Daily	1	2.0	Negative	
Amino acids	Orally	2 g. methionine 1 g. tryptophane	Daily Daily	1 1	4.0 1.5	Negative Negative	
Fresh rumen liquid from cow	Orally	160 ml. (Ave.)	Three times per week	2	4.5	Negative	
Fresh raw milk from cow	Orally	380 ml.	Daily	2	4.5	Negative	

data from the New Hampshire Agricultural Experiment Station suggest that enough injected cobalt might reach the rumen contents under certain conditions to account for the response to cobalt administered in this way. The place where cobalt functions could not be in the intestinal tract because, as shown by Comar and Davis (1947), a considerable fraction of injected cobalt is eliminated through the bile. Thus these results support the belief that the essential function of cobalt is carried out in the rumen.

Cobalt carbonate was fed to six animals at three different levels to see if this relatively insoluble salt was effective in relieving the deficiency. When given orally twice a week in capsules cobalt carbonate appeared to be as effective as the sulfate given as a drench. This bears out the observation from the field that the use of cobalt carbonate in commercial dairy rations is effective in preventing cobalt deficiency in cattle.

The complex mineral mixture was fed to see if this combination of trace minerals might be of value in relieving the deficiency. The nickel was purified of cobalt by the method of Deakin *et al.* (1909). These elements were used because of the frequent inclusion of most of them in commercial mineral mixtures. Very shortly after this treatment started, one animal died. The condition of the other two became progressively worse during the period of the treatment. One of the most noticeable effects from feeding the mineral mixture was a lowering of the erythrocyte count of the blood. Sufficient data are not available to determine if this was caused by an improper balance of the minerals fed or to some other factor. This mixture was of no value in relieving the deficiency.

Various vitamins were fed and injected to see if cobalt deficiency might be due to insufficient synthesis of one or more of these factors in the rumen. The procedure followed in giving the thiamin injections was the same as reported by Ray *et al.* (1948) to bring about improvement in cobalt-deficient sheep. Like all the other B-complex vitamin treatments tried this had no beneficial effect. The thiamin injections could not be continued the full nine weeks as was done by the Wisconsin workers because the condition of the animals had become such that improvement was necessary to save them. The reason for this difference in response of cobalt deficient sheep to thiamin injections is not known.

Liver extract injections alone and with B-complex vitamins did not have any beneficial effects. Tryptophane and methionine were fed because of their relationship to the synthesis of certain B-complex vitamins in the digestive tract. When fed singly or with B-complex vitamins, however, neither of these amino acids brought about any response. Because all of the various combinations of B vitamins appeared to be without value in correcting cobalt deficiency, an effort was made to see if some other factor found in the

normal rumen might be effective in this respect. This was done by drenching cobalt deficient sheep with fresh liquid drawn from the rumen of a normal cow by means of a stomach tube. This treatment also was ineffective. A similar result was obtained from drenching deficient sheep with fresh raw milk. This latter treatment was tried because of recent reports by Schaefer *et al.* (1948) on the presence of unknown dietary factors in milk.

Summary

An experiment was carried out with sheep in an attempt to learn more about the role of cobalt in the nutrition of ruminants. Every animal on the cobalt deficient ration developed marked cobalt deficiency symptoms. All animals which received supplemental cobalt remained healthy. At the time of the first treatment, the cobalt supplemented animals had gained approximately seven times as much in weight, were eating five times as much concentrates, six times as much hay, and were drinking twice as much water as the deficient animals. Wool production of the deficient sheep was approximately 62 percent that of those receiving cobalt.

It was found that both cobalt sulfate and cobalt carbonate relieved the deficiency when administered orally. When injected intravenously, cobalt sulfate brought about a slow response if given daily or in large enough quantities twice a week. B-complex vitamins, liver extract, certain amino acids, a cobalt-free mineral mixture, fresh rumen liquid, and fresh raw milk were all without value in relieving the deficiency.

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THE EFFECT OF COBALT ON THE SYNTHESIS OF VITAMIN B_{12} IN THE RUMEN OF SHEEP[1]

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VERY little information is available on the mechanism by which cobalt exerts its marked effect upon ruminants. Gall *et al.* (1949) have shown that cobalt in the diet is necessary for the maintenance of normal numbers and types of bacteria in the rumen of the sheep. Becker and Smith (1949) found that cobalt-supplemented lambs more efficiently digested the ether soluble and nitrogen-free fractions of the ration than did cobalt-deficient lambs. However, cobalt-deficient lambs showed a significantly greater coefficient of apparent digestibility for the fibrous fractions of the ration. This they attribute to the low feed intake of the cobalt-deficient lambs. Apparently the cellulose splitting microorganisms of the rumen were not affected.

Rubin and Bird (1946) demonstrated that there was a factor in cow manure that would improve growth rate of chicks fed a corn-soybean oil meal diet. Ott *et al.* (1948) obtained maximum growth response in chicks fed a corn-soybean oil meal ration by the addition of vitamin B_{12} or fish solubles. Lillie *et al.* (1948) using chicks were able to show that the factor present in cow manure was in all probability vitamin B_{12}. When Rickes *et al.* (1948) announced that vitamin B_{12} contained cobalt the assumption followed that the vitamin B_{12} present in manure of ruminants would depend upon the amount of cobalt in the ration. This experiment was designed to determine if vitamin B_{12} synthesis in the rumen of the sheep was affected by the cobalt content of the ration.

Materials and Methods

A cobalt-deficient and a cobalt-supplemented lamb were fistulated and fitted with a permanent type lucite cannula to permit removal of large quantities of rumen ingesta. The diet of these sheep consisted of mixed timothy-alfalfa hay, oats, and urea. Cobalt content of the diet as determined by the method of Kidson and Askew (1940) was less than 0.02 p.p.m. The supplemented sheep had cobalt added to the salt at the rate of 1 ounce of $CoSO_4 \cdot 7H_2O$ per 100 pounds of salt. By the use of average figures for salt

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consumption of sheep, the cobalt-supplemented sheep received approximately 1.7 mg. of cobalt daily as compared with 0.03 mg. for the cobalt-deficient sheep.

The rumen ingesta were removed from the sheep in the morning before they had been fed. This was about 15 hours after the previous feeding. By the use of radioactive cobalt, Comar *et al.* (1946) have shown that 51.2 percent of a 174 γ dose was present in the rumen 24 hours after ingestion. It might be expected that synthesis of vitamin B_{12} would be complete at this time. The ingesta were mixed as completely as possible before removal and from ½ to 1 gallon was removed at one time depending upon the amount present in the rumen. Occasionally due to the poor appetite of the cobalt-deficient sheep, less than ½ gallon was removed. There was always at least a one-day interval between days on which the rumen samples were removed. As soon as possible after removal the ingesta were spread on a tray and dried in an oven set at 45–50 degrees centigrade. Rubin and Bird (1946) have shown that there is no loss in the activity of the B_{12}-like factor in cow manure when dried at this temperature. The dried rumen ingesta were ground in a Wiley mill using a 1 millimeter mesh screen. The ground ingesta were stored in dark-colored jars and kept in the dark until mixed with the chick assay ration.

One assay was run on the feces of a cobalt-deficient and a cobalt-supplemented sheep. Feces were collected by means of a sack and harness as described by Garrigus (1934). After the feces had been collected they were prepared for assay by the same procedure as the rumen ingesta.

Day-old straight run (New Hampshire ♂♂ × Single Comb White Leghorn ♀♀) crossbred chicks were used for the assay. They were obtained from the University Poultry Department and were progeny of hens fed diet B1 as described by Robblee *et al.* (1948a). Ten to 15 chicks were used per assay lot depending upon the number available at the time of the assay. All groups were housed in electrically heated batteries equipped with raised screen floors. Feed and water were kept before the chicks at all times. The chicks were weighed at the beginning of the assay and weekly thereafter. The assay ration which had been used by Robblee *et al.* (1948a) was fed to the chicks in this assay. The composition of the ration is shown in table 1.

The material to be assayed was added at the expense of the alfalfa leaf meal so that the crude fiber content could be kept constant for all lots. Iodinated casein[4] was added to all rations at the rate of 0.03 percent. Robblee *et al.* (1948b) reported that the addition of this amount of iodinated casein to the assay ration resulted in a better assay for a factor which in all probability was vitamin B_{12}. Sufficient ration was mixed at the beginning of each

[4] Supplied by Dr. W. R. Graham, Cerophyl Laboratories, Inc., Kansas City, Missouri.

TABLE 1. COMPOSITION OF BASAL DIET FED TO CHICKS

Ground yellow corn	35.0
Soybean oil meal	28.0
Wheat bran	10.0
Wheat middlings	10.0
Vitamin test casein	7.5
Dehydrated alfalfa meal	5.0
Fish oil (400D–2,000A)	0.5
Limestone grit	2.0
Bone meal	1.5
Iodized salt	0.5
Manganese sulfate monohydrate	0.025

Vitamins were added to the basal diet at the following levels

Vitamins	mg./100 gm.
Thiamin hydrochloride	0.3
Riboflavin	0.6
Calcium pantothenate	2.0
Inositol	100.0
Choline chloride	150.0
Pyridoxine hydrochloride	0.4
Nicotinic acid	5.0
Para-aminobenzoic acid	10.0
Biotin	0.02
Folic acid	0.05
Vitamin K	0.05
Vitamin E	0.3

trial to feed the chicks during the full assay period. The rations were stored in covered cans.

The negative controls were fed the basal without supplements. The positive controls had a charcoal adsorbed vitamin B_{12} concentrate added to the basal ration to supply 3 γ vitamin B_{12} per 100 gm. of ration. The test groups received the basal ration plus the various materials to be assayed. The differences in the growth of the groups of chicks receiving samples from the cobalt-deficient and the cobalt-supplemented sheep were tested for significance by the use of the t test as described by Snedecor (1947).

Results and Discussion

The results of the first trial are shown in table 2. A difference of 64 gm was obtained between the negative and positive controls (lots 1 and 2). However, a difference of only 43 gm. was obtained between the rumen ingesta of the cobalt-supplemented and the cobalt-deficient sheep (lots 3 and 4). The group fed the rumen ingesta from the cobalt-supplemented sheep did not attain maximum growth. It is also interesting to note that the rumen ingesta from the cobalt-deficient sheep resulted in a lower growth than did the basal ration (lot 4). Also 33 percent of the chicks in this group died. This

was the highest mortality suffered with any group of chicks during the assay period. When the rumen ingesta from the cobalt-deficient and cobalt-supplemented sheep were assayed a second time (trial II) a difference of 41 gm. was obtained (lots 7 and 8). From these two trials it would appear that some factor(s) was missing from the rumen ingesta of the cobalt-deficient sheep. Addition of vitamin B_{12} to the rumen ingesta of the cobalt-deficient sheep resulted in maximum growth of chicks (lot 5). Also if 2.5 percent rumen ingesta from the cobalt-supplemented sheep were mixed with 2.5 percent rumen ingesta from the cobalt-deficient sheep, maximum growth could be obtained (lot 10). These data indicate that vitamin B_{12} was the limiting factor in the rumen of cobalt-deficient sheep.

TABLE 2. THE EFFECT OF VITAMIN B_{12} AND SHEEP RUMEN INGESTA UPON CHICK GROWTH

Trial no.	Lot no.	Supplement to basal ration	No. of chicks	Av. wt. 4 wk.	
				gm.	
I	1	None	15	226	
	2	B_{12}	15	290	
	3	5.0% rumen ingesta from cobalt-suppl. sheep	15	253	**
	4	5.0% rumen ingesta from cobalt-deficient sheep	15	210	
II	5	None	12	212	
	6	B_{12}	10	321	
	7	5.0% rumen ingesta from cobalt-suppl. sheep	11	298	*
	8	5.0% rumen ingesta from cobalt-deficient sheep	10	257	
	9	5.0% rumen ingesta from cobalt-deficient sheep+B_{12}	10	313	
	10	2.5% rumen ingesta from cobalt-deficient sheep+ 2.5 rumen ingesta from cobalt-suppl. sheep	10	315	
	11	2.5% rumen ingesta from cobalt-suppl. sheep	10	312	
III	12	None	10	189	
	13	B_{12}	10	260	
	14	2.5% rumen ingesta from cobalt-suppl. sheep	10	271	[1]
	15	2.5% rumen ingesta from cobalt-deficient sheep	10	244	
	16	2.5% rumen ingesta from cobalt-deficient sheep+B_{12}	10	286	
	17	2.5% feces from cobalt-suppl. sheep	10	276	**
	18	2.5% feces from cobalt-deficient sheep	10	218	
	19	2.5% feces from cobalt-deficient sheep+B_{12}	10	304	
IV	20	None	10	246	
	21	B_{12}	10	275	
	22	Cobalt (from the sulfate) 0.01%	10	226	
	23	2.0% rumen ingesta from cobalt-suppl. sheep	10	277	
	24	1.5% rumen ingesta from cobalt-suppl. sheep	10	232	
	25	2.5% rumen ingesta from cobalt-suppl. sheep+B_{12}	10	272	

* $P = 0.05$.

** $P = 0.01$.

[1] The difference between lots 14 and 15 was not significant.

Trials were run in order to determine the optimum level at which the rumen ingesta from the cobalt-supplemented sheep should be fed. The results of these indicated that 2.0–2.5 percent of the rumen ingesta contained sufficient vitamin B_{12} for maximum growth (lots 11, 23, and 24) of chicks on this assay. This is in close agreement with the work of Lewis (1949) who assayed a sample of this rumen ingesta using rats and found that 2.5 percent gave maximum growth.

Assay of the rumen ingesta at the 2.5 percent level (lots 14 and 15) gave similar results to the 5 percent level. In this case a weight difference of 27 gm. was obtained. This was the smallest difference obtained with any of the assays. Addition of vitamin B_{12} to the rumen ingesta of cobalt-deficient sheep again gave excellent growth (lot 16).

Feces from cobalt-deficient sheep and cobalt-supplemented sheep gave results similar to the rumen ingesta assays. A difference of 54 gm. was obtained between the two lots of chicks fed feces (lots 17 and 18). Addition of vitamin B_{12} to the feces of the cobalt-deficient sheep resulted in maximum growth (lot 19). Addition of 0.01 percent cobalt (sulfate) to the basal ration caused a marked depression in growth of the chicks (lot 22). Addition of vitamin B_{12} to the ingesta from the cobalt-supplemented sheep did not result in a greater growth of the chicks (lot 25).

Discussion

The data presented here show that vitamin B_{12} synthesis was limited in the rumen of the cobalt-deficient sheep. The level of vitamin B_{12} required to produce maximum growth in chicks with an assay of this type has been shown to be 1.5 γ per 100 gm. of assay ration (Nichol *et al.*, 1949). The level at which the rumen ingesta from the cobalt-supplemented sheep promoted excellent growth in chicks was 2.5 percent. This indicates the rumen ingesta from the cobalt-supplemented sheep contained a minimum of 60 γ of vitamin B_{12} per 100 gm. of dried material. This is in close agreement with Lewis *et al.* (1949) who found 50 γ per 100 gm. with rats as the assay animal when using a sample of the same rumen ingesta used in this study. From this study cobalt appears to be an essential compound in the elaboration of B_{12} in the rumen of the sheep. The specific significance of the production of this vitamin in the rumen remains to be clarified. One explanation is that vitamin B_{12} is required directly by the sheep and there is insufficient production of the vitamin in the rumen of a cobalt-deficient sheep. A second explanation would be that certain of the microorganisms of the rumen cannot utilize cobalt but require vitamin B_{12}. A third explanation could be that vitamin B_{12} is essential for the formation of some unknown factor(s) that is necessary for life in the sheep.

Summary

An assay is described using chicks as the assay animal for determining the relative amounts of vitamin B_{12} in the rumen of cobalt-deficient and cobalt-supplemented sheep.

In 4 chick assays an average difference of 42 gm. growth in 4 weeks was obtained between the rumen ingesta from the cobalt-deficient and the cobalt-supplemented sheep. The rumen ingesta from the cobalt-supplemented sheep gave the larger growth. One assay of the feces from cobalt-supplemented sheep gave 54 gm. more chick growth than did the feces from the cobalt-deficient sheep. The rumen ingesta from the cobalt-supplemented sheep under conditions of this assay contained approximately 60 γ of vitamin B_{12} per 100 gm. of dried rumen ingesta.

These data show that vitamin B_{12} production was limited in the rumen of the cobalt-deficient sheep when compared to the production of the vitamin in the rumen of the cobalt-fed sheep. The possible significance of the production of this vitamin in the rumen is discussed.

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RIBOFLAVIN DEFICIENCY IN THE LAMB[1]

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LITTLE information is available concerning the requirement of the suckling lamb for specific nutrients. Madsen *et al.* (1935) were able to maintain sheep successfully on a synthetic diet for a period of 480 days. However, the purified diet technique used successfully with the calf and pig has so far not been attempted in the case of the suckling lamb. In the case of the calf it was found that deficiencies of biotin, riboflavin and thiamine could be produced using a synthetic milk (Wiese *et al.*, 1946, 1947; and Johnson *et al.*, 1948).

From a qualitative standpoint, it might be expected that the B vitamin requirements of the calf and lamb would be similar. However, since the lamb in relation to its birth weight grows more rapidly than the calf, it is also possible that the quantitative B vitamin requirement may be higher in the case of the lamb. Pearson *et al.* (1946) found that the colostrum and milk of the ewe were richer sources of thiamine, riboflavin, nicotinic acid and pantothenic acid than were the colostrum and milk of the cow. They reported riboflavin levels for the ewe which were from two to three times that found in the colostrum and milk of the cow. It is possible that the higher levels of riboflavin in the colostrum and milk of the ewe indicate a higher riboflavin requirement of the lamb over that of the calf.

In view of these findings it seemed of interest first to determine whether a liquid purified diet could be devised which would support normal growth of the young lamb and, second, to determine the effects of riboflavin deficiency by the use of such a diet.

Experimental

Lambs of both the mutton and fine wool type were used in this experiment. The lambs were 3–4 days of age and had received colostrum. All of the animals were kept in concrete-floored pens and were changed from one pen

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to another every other day. The pens were then cleaned and disinfected in order to avoid, as far as possible, complications with outside diseases. Burlap bags containing wood shavings were used for bedding. The composition of the purified diet fed is shown in table 1. The fat soluble portions of the diet were homogenized with the suspension of casein, glucose, lactose and salts in a Manton-Gaulin homogenizer. The method employed was similar to that

TABLE 1. COMPOSITION OF THE PURIFIED DIET

Component	%	Vitamins	Mg. per kg. of liquid diet
Casein (Labco)	30	Thiamine	1.4
Glucose	28	Riboflavin	3.0
Lactose	10	Nicotinic acid	4.0
Lard	26	Calcium pantothenate	5.0
Salts*	6	Pyridoxine	2.0
		Pteroyl-glutamic acid	0.2
		p-Aminobenzoic acid	4.0
		Inositol	40.0
		Biotin	0.04
		Choline	400.0
		α-Tocopheral acetate	2.0
		2-Methyl naphthoquinone	0.4
		Vitamin A	4000 I.U.
		Vitamin D	500 I.U.

* The salt mixture was similar to the one described by Johnson, James and Krider, JOURNAL OF ANIMAL SCIENCE 7, 486 (1948).

described by Wiese *et al.* (1947b). The liquid purified diet contained 16% solids. All of the lambs were fed from bottles five times a day.

Results and Discussion

The growth response of lambs fed the control diet is shown in figure 1. The average daily gain of the control lambs was 0.50 lb. over the thirty-six day period. Kean and Henning (1949) in a study of the daily gains of 787 lambs from birth to 32–36 pounds body weight found an average gain of 0.53 lb. per day. Thus, the growth of the control lambs compared favorably with the growth of lambs under more natural conditions. The control lambs consumed an average of 0.54 of dry matter daily and required 1.08 lbs. of dry ration to produce 1 lb. gain in body weight. Five of the control lambs were necropsied at the end of the thirty-sixth day and a pathological examination of internal organs revealed no abnormalities of any kind.

The overall growth response of the 7 lambs fed the riboflavin-deficient

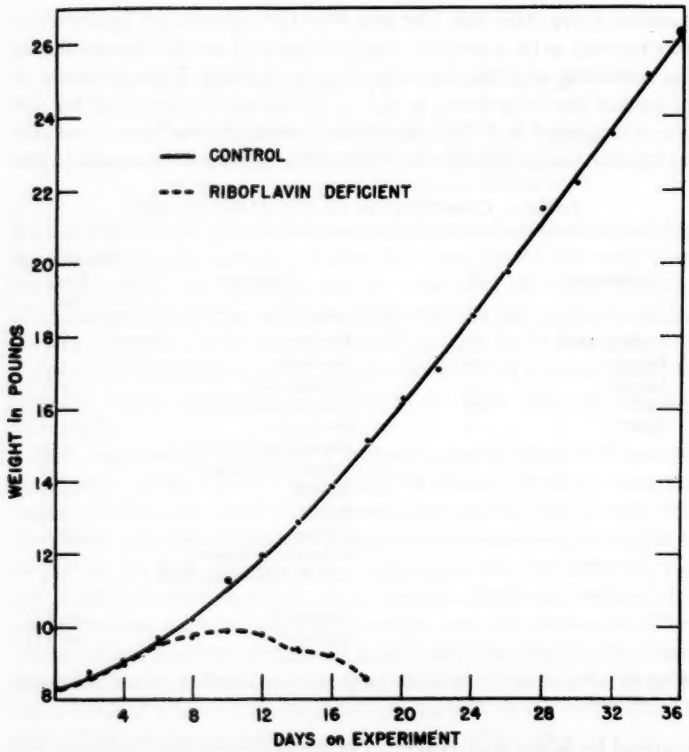

Figure 1. Average growth response of control and riboflavin-deficient lambs.

TABLE 2. GROWTH RESPONSE OF EXPERIMENTAL LAMBS

	Control	Riboflavin deficient
Number animals	8	7
Initial age, days	3–5	3–4
Av. initial weight, lbs.	8.3	8.1
Av. eighteen day weight, lbs.*	15.2	8.6
Days on experiment	18	14–18
Av. daily gain, lbs.	0.38	0.03
Av. daily dry matter consumed, lbs.	0.36	0.14
Lbs. dry matter per lb. gain	0.95	4.75

* The control lambs were fed the same diet for 36 days.

diet is shown in table 2. Since none of the lambs were fed the riboflavin-deficient diet beyond the eighteenth day, a strict comparison of the control and riboflavin-deficient groups would, of necessity, take into account the growth performance of the control lambs for only the first eighteen days. Thus, the average growth performance of the control lambs as shown in table 2 represents only the first eighteen days of the trial. Growth data covering the thirty-six day feeding period of the control lambs is given above. The average daily gain of 0.03 lb. for the riboflavin-deficient lambs as compared to an average daily gain of 0.36 lb. for the control group indicates that the young lamb has a definite requirement for riboflavin. Figure 1 shows the average growth response of the riboflavin-deficient lambs. It can be seen that the lambs fed the riboflavin-deficient diet grew at a normal rate for approximately 6 days. From the sixth to the twelfth day of the experiment the appetites of the animals declined and their weights remained more or less stationary. However, after the twelfth day the appetites declined still further and the animals lost weight. It was noted that at approximately the twelfth day the riboflavin-deficient lambs apparently had difficulty in breathing. This labored breathing closely resembled symptoms of pneumonia. It was interesting to note that none of the oral lesions of riboflavin deficiency observed in calves (Wiese *et al.*, 1947) were noted in the riboflavin deficient lambs. The wool coat of the lambs appeared normal and no scours or excessive lachrymation were noted. On the sixteenth day of the trial two of the lambs died and by the eighteenth day the remaining lambs were in a moribund state.

From the twelfth to the eighteenth day of the experiment all of the lambs were placed in metabolism cages and a 24-hour collection of urine obtained for riboflavin analysis. The riboflavin assay was carried out microbiologically using the organism *Lactobacillus casei*. The average urinary excretion of riboflavin for the control lambs was 0.50 mg. per 24 hours as compared with 0.01 mg. per 24 hours for the riboflavin-deficient group. Hemoglobin levels in both groups were about the same with values ranging from 11 to 13 gm. per 100 ml. of blood. The most significant difference between the control and riboflavin deficient lambs was found in the leucocyte count. In the control lambs the leucocyte count taken from the twelfth to the sixteenth day ranged from 6,000 to 8,000 cells per $mm.^3$ as compared with 10,000 to 15,000 for the deficient lambs. This increase in leucocyte count was reflected in a reversal of the differential count (polymorphonuclear leucocyte to lymphocyte).

Pathological studies of the five riboflavin-deficient lambs revealed the following: (1) Fatty degeneration of the hepatic cells of the liver and fatty degeneration of the cortex of the kidneys; (2) Lung involvement with

bronchopneumonia. This type of pneumonia is characterized by solidification of the lobes to varying degrees. These lung abnormalities are very characteristic of pneumonia as seen in lambs in the field. Culture studies of the lung tissue revealed the presence of Pasturella organisms. This and other organisms are also associated with lamb pneumonia as seen under field conditions (Spray, 1923).

Two of the seven lambs on the riboflavin-deficient diet were treated with riboflavin on the sixteenth day of the trial. Both lambs showed symptoms of pneumonia as evidenced by an elevated leucocyte count and labored breathing. Since the appetites were very poor an intraperitoneal injection of 0.5 gm. of riboflavin was given to each lamb. Riboflavin was also added to the diet in the amount shown in table 1. A very prompt increase in appetite was apparent in both lambs after 24 hours and the animals were gaining weight by the third day. The two lambs were fed until a weight of 25 pounds was reached and then necropsied. The livers and kidneys were normal and the lung tissue, although healed, showed evidence of past infection. These results indicate that the pneumonia produced was, in some way, related to riboflavin deficiency. Whether the pneumonia produced by riboflavin deficiency has any relationship to the pneumonia as seen under field conditions is not known. Venkatachalam *et al.* (1949), in a study of the various causes of death in young lambs, found that out of 483 lambs studied, pneumonia was responsible for almost one-third of the deaths.

Summary

1. Three-day old lambs were successfully raised on a liquid purified diet.

2. The lamb, in the pre-ruminant stage, has a definite requirement for riboflavin.

3. Symptoms of riboflavin deficiency were lowered appetite, poor growth and finally pneumonia.

4. Symptoms of riboflavin deficiency were rapidly alleviated with riboflavin administration.

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THE MINIMUM PHOSPHORUS REQUIREMENT OF LAMBS FOR PHOSPHORUS EQUILIBRIUM[1]

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IN REVIEWING the mineral nutrition of farm animals, Mitchell and McClure (1937) pointed out the need for further information on the calcium and phosphorus requirement of sheep. Several years later Beeson and associates (1944) (1945) reported the results of their studies of the phosphorus requirement of fattening lambs and ewes for gestation and lactation. In an extensive series of feeding trials, these investigators found that for fattening lambs a level of 0.12 percent of phosphorus in rations was inadequate, 0.14 percent was borderline, and 0.15 percent or more of phosphorus was adequate as judged by the rate of gain, efficiency of feed utilization, and maintenance of blood phosphorus levels. From these results, the minimum phosphorus requirement of fattening lambs appeared to be close to 2.17 grams daily per 100 pounds of live weight. The requirement for lactation was found to be higher than that for fattening or gestation. References to related investigations of phosphorus metabolism in sheep are given in the above mentioned publications.

Experimental

An opportunity to determine the phosphorus requirement of lambs by balance procedures became available during an investigation of the nitrogen metabolism of lambs on rations containing different amounts of urea. A few experiments were conducted for the specific purpose of determining the effect of urea on phosphorus retention. The results, which are reported in the present paper, find application in establishing the minimum phosphorus requirement of lambs in addition to showing the negligible effect of urea on this requirement.

The experiments were conducted during the years between 1945 and 1950 with growing wether lambs. The lambs, which were of mixed breeding, came from Texas ranges and Oklahoma farms and were selected each year for uniformity of age, size and weight. Approximately 15 days were required to get the lambs on a constant daily feed intake preceding the balance trials.

The manner of conducting the balance trials was essentially that described in previous papers (Dinning *et al.*, 1949; Briggs and Gallup, 1949). It should

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be added, however, that particular care was taken in these trials involving phosphorus to protect experimental material from the usual sources of mineral contamination. Hydrochloric acid was used in the preservation of urine to prevent the precipitation of calcium phosphate. Daily aliquots of feces and urine were preserved separately and recombined in the proper proportion at the termination of each 10-day trial for chemical analysis. Roughage feeds were sampled daily, and concentrate feeds were thoroughly mixed and sampled preceding each trial. Phosphorus and calcium were determined on

TABLE 1. COMPOSITION OF BASAL RATIONS FOR LAMBS[1]

Ingredients	Daily amount supplied by ration no.									
	1	2	3	4	5	6	7	8	9	10
	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
Prairie hay	—	636	636	636	508	218	218	—	—	—
Cottonseed hulls	340	—	—	—	—	—	—	600	350	200
Concentrates[2]	358	57	59	171	58	433	435	103	353	503
Total	698	693	695	807	566	651	653	703	703	703
Protein[3]—percent	13.08	7.22	6.91	11.01	8.12	10.67	10.00	6.69	6.81	6.44
Calcium[3]—percent	0.14	0.76	0.84	0.73	0.51	0.22	0.21	0.30	0.28	0.24
Phosphorus[3]—percent	0.19	0.13	0.22	0.25	0.17	0.30	0.28	0.19	0.18	0.19

[1] In addition, the lambs received daily about 15 gm. of iodized salt and 1 ml. of fortified codliver oil.

[2] Concentrates composed of corn, corn gluten meal, cottonseed meal, hominy feed, molasses, and starch in varying proportions. Phosphorus was increased in ration 3 by the addition of 2.4 gm. NaH_2PO_4 and in rations 9 and 10 by additions of 2.6 gm. and 1 gm., respectively, of $Ca_3(PO_4)_2$.

[3] Dry matter basis.

representative samples of these materials by accepted methods (A.O.A.C., 1945).

The different basal rations, which varied widely in their proportions of roughage and concentrate feeds, are shown in table 1. To secure the desired variation in phosphorus intake, the phosphorus content of rations 3, 8, and 9 was adjusted by the addition of sodium and calcium phosphates. Calcium carbonate was used in adjusting the calcium content of rations 9 and 10 to the desired level. A supplemented ration was made from each of the basal rations by the direct addition of urea. The two rations were then compared in balance trials involving eight lambs in all comparisons except those made with rations 2, 3 and 9 where four lambs were used.[3]

Results and Discussion

The results of the phosphorus balance trials and other pertinent data

[3] Grateful acknowledgment is made of the capable assistance of Eldred Harris, J. S. Dinning and L. S. Pope in collecting samples and providing for the care of the various groups of lambs in different years.

TABLE 2. DAILY INTAKE AND RETENTION OF PHOSPHORUS BY LAMBS RECEIVING RATIONS WITH AND WITHOUT UREA SUPPLEMENTATION

Ration numbers[1]	Ca:P ratio	Number of trials	Weight of lambs	Daily intake of				Daily phosphorus balance
				Total nitrogen	Urea nitrogen	Total phosphorus	Phosphorus per 100 lb. live weight	
			lbs.	gm.	gm.	gm.	gm.	gm.
2	5.6	5	60	7.33	—	0.86	1.43	−0.09
2u	5.6	5	62	8.42	1.09	0.86	1.39	−0.06
5	3.0	8	54	6.71	—	0.90	1.66	−0.06
5u	3.0	8	55	8.89	2.18	0.90	1.63	−0.07
9	1.3	4	67	7.02	—	1.33	1.98	−0.06
9u	1.5	4	65	10.46	3.77	1.20	1.85	−0.13
1	0.7	8	62	13.31	—	1.23	1.98	−0.09
1u	0.7	8	64	20.16	6.85	1.20	1.88	−0.14
8u	1.6	8	63	10.78	3.77	1.23	1.95	+0.10
10	1.2	8	66	6.78	—	1.25	1.89	+0.14
10u	1.3	8	68	10.55	3.77	1.25	1.88	+0.23
3	3.8	4	66	7.11	—	1.41	2.14	+0.09
3u	3.8	4	65	8.20	1.09	1.41	2.14	+0.14
7	0.8	8	69	9.41	—	1.66	2.41	+0.48
7u	0.8	8	69	11.69	2.28	1.66	2.41	+0.50
6	0.7	8	69	10.02	—	1.73	2.51	+0.45
6u	0.8	8	69	11.16	1.14	1.73	2.51	+0.58
4	2.9	9	65	13.06	—	1.88	2.89	+0.28
4u	2.9	9	67	16.35	3.29	1.89	2.82	+0.27

[1] The letter "u" denotes supplementation with urea.

are presented in table 2. For convenience of comparison the different pairs of rations have been arranged in table 2 in order of their increasing phosphorus content.

From the results obtained with the basal ration and the corresponding supplemented ration in each of the various pairs, it is apparent that urea in the amounts fed was without effect on phosphorus retention. Urea supplied over 30 percent of the total nitrogen in some of these rations. The lambs were in positive nitrogen balance during all periods except when ration 8u

was fed. This ration contained a high percentage of cottonseed hulls of low digestibility. Results obtained with the unsupplemented ration 8 are not presented because of errors in its formulation.

Negative phosphorus balances were obtained with the two pairs of rations (2 and 5) which furnished less than 1 gram of phosphorus per day. Both positive and negative balances were obtained with the paired rations 1, 9 and 10 and ration 8u, each of which furnished about 1.23 grams of phosphorus per day. Differences in the amounts of phosphorus retained on the above rations were small and could not be related to differences in type of rations or Ca:P ratios. Positive balances were obtained with all other rations which furnished from 1.41 grams to 1.89 grams of phosphorus per day. The magnitude of the positive balances favored rations 6 and 7 which contained a high percentage of concentrates over rations 3 and 4 which were high in roughage and had wide Ca:P ratios. Evidently phosphorus equilibrium was reached with those rations which supplied the lambs with from 1.9 grams to about 2.1 grams of phosphorus per 100 pounds of live weight.

The results are in general agreement with those of Beeson and associates (1944) in showing that for lambs weighing about 65 pounds the minimum daily phosphorus requirement is approximately 2 grams per 100 pounds of live weight. Likewise, there is agreement between the two sets of data in that an optimum phosphorus requirement of 2.4 grams per 100-pounds live weight, as suggested by the Idaho work (Beeson *et al.*, 1944), permitted a marked increase in phosphorus retention in the present study.

Although calcium balances were calculated in all trials, the results are not presented in table 2 because absolute values were assured only in trials involving paired rations 6, 7, 8, 9 and 10. Urea was found to be without effect on the amount of calcium retained in these trials. Slightly negative calcium balances of 0.08 gram and 0.06 gram were obtained with the paired rations 9 and 10, respectively, and a positive balance of 0.16 gram with ration 8u. Since the Ca:P ratio of these rations was over 1, the balances provide evidence that the calcium requirement was somewhat greater than the minimum phosphorus requirement at phorphorus equilibrium. When larger amounts of phosphorus but smaller amounts of calcium were supplied, as with paired rations 6 and 7 having Ca:P ratios of 0.8, positive calcium balances were obtained which varied from 0.09 to 0.13 grams. Apparently calcium was more efficiently utilized at these higher levels of phosphorus intake.

Summary

Phosphorus balance procedures were used to determine the minimum phosphorus requirement of lambs weighing from 55 to 70 pounds, and to determine the possible effect of urea on this requirement. Limited informa-

tion on the calcium requirement of lambs was also obtained in this study. The ten rations used varied from 0.13 percent to 0.30 percent in phosphorus and from 0.14 percent to 0.84 percent in calcium.

Addition of urea as a nitrogen supplement to each of these rations was without effect on phosphorus and calcium retention.

Phosphorus balances were negative with rations which supplied from 1.4 to 1.7 grams of phosphorus daily, per 100 pounds of live weight (26 trials), about equally positive and negative with those that supplied from 1.9 to 2.1 grams of phosphorus (56 trials), and positive without exception with those that supplied from 2.4 to 2.9 grams of phosphorus (50 trials).

At phosphorus equilibrium (2 grams of phosphorus per 100 pounds of live weight) the calcium requirement appeared to be slightly greater than the phosphorus requirement.

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THE EFFECT OF FEEDING CONCENTRATES TO RANGE EWES ON LAMB AND WOOL PRODUCTIVITY[1]

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THE influence of the nutrition of the breeding ewe on growth and survival of progeny has long been recognized as important. The problem is to provide the ewe flock with a ration which is adequate in terms of nutrients but at the same time is economical. In the western states ewes in early and mid-pregnancy are fed concentrates only in the event that the range is scanty or that the hay is of poor quality. However, feeding concentrates in late pregnancy is much more a common practice even when the hay fed is a good quality legume.

Several recent investigations have shown that extreme differences in levels of feeding ewes during pregnancy affects the birth weight of lambs. Thompson and Fraser (1939) noted that the lighter weight lambs at birth resulting from a low plane of nutrition of the ewe lacked vitality and reported that concentrate feeding one month before lambing corrected this effect. Underwood *et al.* (1943) found that supplementing pregnant ewes with one-half pound each of wheat and linseed meal per head per day increased birth weight and growth rate of lambs but not sufficiently to make economic such a high level of feeding. When pregnant ewes were supplemented at a lower level (one-half pound wheat per head per day) Underwood and Shier (1942) were unable to note any effect on birth weight, growth rate, or slaughter weight of lambs. However, they found that feeding at this level resulted in a significant reduction in losses of ewes and lambs due to pregnancy toxemia. Wallace (1948) studied the effect of extreme levels of diet upon pregnant ewes during two periods: early pregnancy and late pregnancy. He concluded that the level of nutrition actually prevailing during the period over which the gravid uterus is making maximum growth is more important than the state of body reserves of the mother at that time. Williams, *et al.* (1950) reported on a cooperative experiment with pregnant ewes involving five experiment stations in Canada. They concluded that legume hay gave more satisfactory results than did non-legume hay as indicated by ewe body weight, lamb weight, and vigor of lambs at birth. They found that a

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"change-over" ration in which non-legume hay was fed during the early pregnancy period and legume hay during late pregnancy gave results comparable to those obtained when legume hay was fed for the entire pregnancy period.

Ewes are sometimes fed concentrates also before and during the breeding period. This practice, called flushing, is generally considered beneficial for ewes in thin condition and results in high fertility. However, Darlow and Hawkins (1933) and McKenzie and Phillips (1933) suggest that this practice also allows the ewes to be bred earlier.

Much of the experimental work appearing in literature on the nutrition of the pregnant ewe is based on extremes in levels of nutrition. The purpose of the experiment to be reported here was to find the value of feeding concentrates to range ewes handled more or less under typical western conditions and fed typical western rations.

In order to make the experiment more comprehensive the reproductive period over which ewes are commonly fed supplements was divided into four physiological stages, i.e., pre-breeding, breeding, early pregnancy, and late pregnancy. The four feeding periods plus the factor of ewe condition were combined in a 2^5 factorial design (Yates, 1937), in order to evaluate main effects and possible interactions among these. The effect is measured in terms of body weight and fleece weight of the ewe, birth weight and weaning weight of lambs, number of lambs born alive and survival of lambs to weaning. A secondary objective of this report is to illustrate the use of a factorial experiment in pursuing investigations under practical conditions such as the handling of livestock on the range.

Experimental

A flock of grade Columbia ewes maintained in connection with the sheep improvement program of the Montana Agricultural Experiment Station, Bozeman, for the year 1944–1945 provided the animals for this experiment. While the flock was called grade Columbias, they actually represented Columbia-Rambouillet crossbreds, and first, second and third backcrosses to the Columbia. The ewes with different amounts of Columbia blood were allotted to the treatments equally. In addition, the age factor which varied from two to five years was minimized similarly by apportioning the age groups equally to the different treatments.

The five factors included in the experiment were:

a Feeding supplement during the pre-breeding period, October 13 to October 27 (14 days); none or ½ pound concentrates daily per ewe.

b Feeding supplement during the breeding period, October 28 to December 7 (40 days); none or ½ pound concentrates daily per ewe.

c Feeding supplement during the early pregnancy period, December 8 to March 16 (99 days); none or ½ pound concentrates daily per ewe.

d Feeding supplement during the late pregnancy or pre-lambing period, March 17 until the lambs were dropped; none or ½ pound concentrates daily per ewe.

e Condition of the ewes at the commencement of the experiment; poor or good.

All possible combinations of these factors resulted in 32 sub-treatments. Reference to treatments will be denoted by the letters used above, *a* to *e*. This is in accord with Yates' (1937) terminology. For example, treatment *bce* is to be read as that group of ewes which were fed concentrates during the breeding and early pregnancy periods and were in good condition at the commencement of the experiment. It is to be noted that *a* and *d* are omitted from the treatment combination showing that this group of ewes received no concentrates during the pre-breeding and late pregnancy periods. The capital letters A, B, etc. will denote the main effects, that is, the mean response to treatments *a*, *b*, etc. and AB, AC, etc. will denote interactions.

The supplement fed was beet pulp pellets except that for about one week during period *d* the ewes were fed oats when the supply of pellets ran out. During periods *a* and *b* the ewes were maintained on a winter grazing area located in the mountain foot-hills at an elevation of about 5,000 ft. The type of vegetation grazed was primarily native grasses typical of the central-mountain range country of Montana.[3]

The condition of the winter range during the fall of 1944 was good but a heavy snow prompted the feeding of hay beginning on December 8. From this date to March 1, mixed hay was fed. This hay was generally of fair quality but varied considerably in species composition. However, all of it contained approximately a third to a half legume (alfalfa or clover) with the balance being native or tame grasses. After March 1, all ewes were fed a good quality first or second cutting alfalfa hay.

Condition of the ewes was determined by handling at the commencement of the experiment when initial weights were taken. Three arbitrary classes for condition were used but re-examination of the ewe weights suggested that the ewes fell into only two well defined classes; the mean weights were 143.0, 132.5 and 127.8 pounds per ewe for the good, fair and poor condition classes, respectively. The last two classes were combined into one "poor condition" class which averaged 11.6 pounds less than the "good condition" ewes. This regrouping also served to reduce disproportionality since the 127.8 pound class contained only 61 of the original 462 ewes.

[3] Dominant species: Agropyron smithii, Agropyron spicatum, Festuca idahoensis, and Bouteloua gracilis.

Paint brands served to identify the ewes fed concentrates during any one period, with different colors used in the successive periods. The flock was split with a cutting gate each evening into two groups. One group was fed the concentrates and the other received none. After feeding, the two groups were recombined again. Usually the whole operation was accomplished by one man in less than an hour. It will be noted that the operation of this experiment is extremely simple. From the standpoint of flock management the total cost of the experiment was therefore very low.

The data obtained included weights of the ewes at the beginning of the experiment and at the end of each feeding period. Fleece weights of the ewes were obtained at shearing time. Birth date, weight and sex of the lambs were recorded. The ewes and their lambs were on range until September 4 or 5 at which time the lambs were weaned and their weights recorded.

Statistical Treatment

In the analysis of the weights at birth and at weaning, differences due to sex and twinning, which were not of particular interest in the present study were removed before analysis of treatment effects. Patterson (1946) has outlined a method of correcting for such effects so that their net contribution to the analysis of variance is negligible. By this procedure, all lamb weights were adjusted to a female single lamb basis.[4]

As is often the case with experimental data involving animals, disproportionate subclass numbers are encountered. However, the 2^5 classification of treatment effects in the present case considerably simplifies the problem in this respect. Assuming interactions present the approximate analysis becomes that of unweighted means (Yates, 1933, 1934). This provides a rigorous method for the analysis of 2^n classifications (Yates, 1933), but is only approximate for the general $R \times C$ case (Snedecor, 1946). The method has been illustrated with numerical examples by Snedecor and Cox (1935) and by Snedecor (1946).

Since interest is divided more or less equally between main effects and interactions, the method of unweighted means was used in those cases where a detailed analysis of the treatment effects was made. The analysis is carried out on the 32 subclass means in the ordinary way and the appropriate experimental error for testing the effects and interactions is derived from the mean square within subclasses. This mean square is obtained from a single classification analysis of the individual data on the basis of unequal numbers in the treatments, Snedecor (p. 240, 1946). After dividing by the harmonic mean of the subclass numbers this mean square is comparable to the mean

[4] This caused the general mean of the corrected values to be greater than the uncorrected general mean, and as a result the total variance is reduced. However, this does not bias the data in any other way.

TABLE 1. MEANS OF 32 SUBCLASS TREATMENTS ON THE EWE

Initial condition of ewes	Periods fed concentrates	Number of ewes	Av. initial weight	Av. gains to March 16	Av. fleece weight	Av. date of lambing
			(Lbs.)	(Lbs.)	(Lbs.)	(April)
Poor	None	15	129.2	13.4	9.5	6
	a	15	133.5	10.8	9.4	7
	b	16	126.6	12.8	9.4	9
	c	15	129.3	19.0	10.0	5
	d	18	128.2	11.1	10.7	9
	ab	20	132.8	11.9	9.7	7
	ac	20	137.8	17.5	10.1	5
	ad	15	133.9	9.6	10.0	10
	bc	19	136.4	16.3	10.5	10
	bd	15	128.1	8.8	9.9	5
	cd	14	136.1	19.8	11.2	7
	abc	20	131.7	18.0	10.2	9
	abd	11	135.4	13.4	9.8	9
	acd	12	129.2	22.6	10.1	7
	bcd	18	134.4	22.4	10.3	5
	abcd	15	127.8	22.3	9.7	6
Good (e)	None	15	132.4	5.7	9.8	7
	a	13	144.5	9.0	10.1	7
	b	8	147.0	15.8	9.3	16
	c	9	138.0	19.6	10.7	13
	d	13	143.6	12.8	9.6	5
	ab	11	153.0	15.3	10.9	3
	ac	10	145.6	18.6	10.4	7
	ad	15	143.6	12.8	9.6	8
	bc	8	141.5	21.0	9.8	6
	bd	11	145.1	10.2	10.5	8
	cd	18	135.2	16.9	9.6	11
	abc	9	138.6	21.6	10.5	5
	abd	20	144.3	14.3	9.9	5
	acd	16	141.1	20.2	11.0	5
	bcd	12	144.3	20.2	9.8	3
	abcd	14	149.6	25.1	10.2	5

squares calculated from the treatment means. This procedure was used to analyze birth weights, weaning weights, and ewe gains.

No entirely satisfactory procedure was found to analyze interactions of the enumeration data on the size of lamb crop. A simple analysis of variance of 32 items was used but the error variance in this case is probably too large. For testing main effects chi square was employed in addition to the analysis of variance.

Results and Discussion

The results of the experiment are presented in two parts. In the first part feeding and condition are considered as they affect body weight, fleece

weight and date of lambing. In the second part the treatments are considered as they affect the lamb crop. This includes birth weights and weaning weights of lambs, the total number of lambs born, and the number of lambs surviving to weaning age.

Feeding Effects Observable in the Ewe

The ewes were considered only from the start of the experiment when initial weights were taken and up to lambing time. The data also included fleece weights taken at shearing time. The results are summarized in table 1 for the 32 sub-class treatments, and in table 2 for the 5 main treatments.

Body Weight and Gains. Since the ewes were weighed at the commencement of the experiment and again at the end of each of the four feeding periods, an analysis of the gains made in separate periods was possible. However, no analysis was made of gains in the fourth period because the records were incomplete.

Analyses of variance of ewe weights and gains were made but are not

TABLE 2. EFFECTS OF FIVE MAIN TREATMENTS ON THE EWE

Treatment	Number of ewes	Av. initial weight	Av. gains to March 16	Av. fleece weight	Av. date of lambing
		(Lbs.)	(Lbs.)	(Lbs.)	(April)
a. Pre-breeding					
Fed	236	138.9	16.2	10.08	7
Not fed	224	136.0	15.1	10.09	8
Difference		+2.9	+1.1	−.01	−1
b. Breeding					
Fed	227	138.5	16.7	10.05	7
Not fed	233	136.3	14.7	10.12	7
Difference		+2.2	+2.0	−.07	0
c. Early Pregnancy					
Fed	229	137.3	19.8	10.27	7
Not Fed	231	137.6	11.6	9.90	7
Difference		− .3	+8.2	+.37	0
d. Late Pregnancy					
Fed	237	137.5	16.4	10.13	8
Not fed	223	137.4	14.9	10.03	7
Difference		+ .1	+1.5	+.10	+1
e. Condition					
Good	202	142.9	15.7	10.10	7
Poor	258	131.9	15.7	10.07	7
Difference		+11.0	0.0	+.03	0

TABLE 3. ANALYSES OF VARIANCE FOR BIRTH DATE, BIRTH WEIGHT, WEANING WEIGHT, AND FLEECE WEIGHT

Preliminary Analyses

	d.f.	M.S. birth wt.	d.f.	M.S. date lambing	d.f.	M.S. weaning wt.	d.f.	M.S. fleece wt.
Between Treatments	31	5.22**	31	85.16**	31	103.18	31	2.69*
Within Treatments	544	2.89	405	39.76	405	101.04	340	1.68

Detailed Analyses (based on means of classes rather than sums)

Treatment effects	d.f.	Mean squares for			
		Date lambing[1]	Birth wt.	Weaning wt.	Fleece wt.
A	1	11.98	0.384	8.72	0.026
B	1	1.46	0.304	0.34	0.096
C	1	5.33	0.052	4.58	1.074**
D	1	8.53	0.076	12.88	0.089
E	1	0.05	0.253	15.82	0.045
AB	1	1.38	0.027	17.55	0.098
AC	1	0.15	0.028	0.58	0.010
AD	1	12.90*	0.687*	9.35	0.383
AE	1	29.15**	0.385	3.85	1.096**
BC	1	5.28	0.366	0.02	0.186
BD	1	17.61**	0.039	43.01*	0.142
BE	1	9.03	0.250	16.96	0.069
CD	1	2.10	0.640	0.16	0.153
CE	1	0.11	0.024	0.88	0.099
DE	1	6.84	0.348	23.63	0.528
Remainder	16	7.24	0.290	8.47	0.201
Individuals[2]		3.14	0.174	7.99	0.157

[1] Days from April 1.
[2] Same as for "Within Treatments" in the Preliminary Analyses given above.
* $P < .05$.
** $P < .01$.

presented here. The findings, however, are readily interpretable and need only be stated briefly. The 11.6 pound mean difference between thin ewes and good condition ewes represents an initial difference in body weight associated with condition. In period *a* the average gain of thin ewes on feed was 3.2 pounds and 2.7 pounds without feed. The good condition ewes gained only an average of 1.8 and 1.6 pounds with and without supplement, respectively. The effect of condition on gain was significant.

In period *b* the thin ewes on feed gained more than the good condition ewes on feed. Also the good condition ewes not supplemented lost more weight than the poor condition ewes not supplemented.

Feeding in period *c* also showed a substantial effect on gains. Pregnant ewes in good condition showed greater body weight increases than thin ewes regardless of feed.

The mean gains to March 16 given in tables 1 and 2 represent the cumulative picture of gains over the first three periods. Substantial gains are recorded even where no supplement was provided. This is to be expected for ewes that are pregnant. The greatest effect of supplement is observed in period *c* as would be anticipated because this was the longest feeding period.

Fleece Weight. The fleece weights of 372 ewes were available for analysis. Table 2 shows that the ewes given the supplement in period *c* sheared .37 pound heavier fleece than those which did not receive the supplement. The analysis of variance given in table 3 indicates that this difference is highly significant. Apparently, the effect of feed in the other periods on wool growth is negligible. The positive effect of feeding concentrates in *c* is readily accepted when it is remembered that this period extended for 95 days. The significance of the AE interaction in table 3 is not readily interpretable biologically, and therefore is considered as a chance difference.

Date of Lambing. Variation among mean lambing dates might be expected on the hypothesis that feeding and management influence the estrous cycle and the length of gestation period. Examination of the mean lambing dates given in table 1 shows a range of 13 days among the subclass means of those ewes in good condition. In contrast there is a spread of only 5 days among the subclasses of the thin ewes. It appears that the good condition ewes tend to vary more in time of conception. Table 3 shows that the differences in lambing dates among the 32 subclass treatments are highly significant but that there are no significant differences between treatments in each of the five main classifications. Yet several of the interactions among the five main effects show significance. The interaction, AE, may be reconstructed from table 1 as follows:

	Average Lambing Dates of		
	Thin ewes	Good ewes	Difference
Ewes not supplemented in *a*	5.6	8.6	−3.0
Ewes supplemented in *a*	7.5	7.0	+0.5

It appears that thin ewes not receiving any supplement in *a* conceive earlier than good condition ewes. Feeding in period *a* (flushing) tends to wipe out this initial difference due to condition.

TABLE 4. MEANS OF 32 SUBCLASS TREATMENTS ON THE LAMB CROP

Condition of ewes	Periods fed conc.	No. of ewes	Birth weight	Weaning weight	Number of lambs per 100 ewes			
					Born	Born dead	Dead or missing to weaning	Weaned
			(Lbs.)	(Lbs.)				
Poor	None	15	11.5	84.8	100	7	0	93
	a	15	10.8	76.9	133	20	26	87
	b	16	10.6	78.9	100	12	13	75
	c	15	11.5	83.2	107	7	13	87
	d	18	10.2	77.2	100	11	6	83
	ab	20	10.0	79.3	130	10	55	65
	ac	20	11.8	78.9	115	10	35	70
	ad	15	11.6	79.4	127	14	20	93
	bc	19	10.8	73.5	132	11	5	116
	bd	15	10.9	77.3	120	13	20	87
	cd	14	11.4	75.9	114	14	14	86
	abc	20	10.4	78.9	130	25	10	95
	abd	11	12.1	77.1	127	9	9	109
	acd	12	11.3	81.3	125	0	25	100
	bcd	18	10.9	80.4	128	17	28	83
	abcd	15	10.6	82.2	140	7	6	127
Good (e)	None	15	10.2	78.7	120	13	20	87
	a	13	11.1	76.4	131	16	0	115
	b	8	11.4	72.8	138	0	5	88
	c	9	10.8	81.6	156	12	22	122
	d	13	11.6	80.0	123	0	15	108
	ab	11	11.1	82.9	154	18	27	109
	ac	10	12.4	81.1	120	0	30	90
	ad	15	11.6	80.0	133	0	20	113
	bc	8	11.6	79.8	88	0	0	88
	bd	11	10.7	82.4	154	9	45	100
	cd	18	11.0	77.8	133	0	16	117
	abc	9	11.1	78.6	122	33	0	89
	abd	20	11.4	85.1	130	20	15	95
	acd	16	11.0	80.4	119	13	12	94
	bcd	12	10.2	83.8	125	25	17	83
	abcd	14	11.6	85.1	150	7	29	114

Feeding Effects Observable in the Lamb Crop

The history of the lamb crop is given in this experiment from birth to weaning. Table 4 contains the results of the 32 subclass treatments and table 5 summarizes the results of the five main treatments. Tables 3 and 7 contain the statistical analyses. Table 6 shows the differential response to feeding of poor and good condition ewes.

Birth Weight. Data on 576 lambs born were used in the analysis. These are the progeny of 433 of the original 462 ewes started on the experiment. All lambs born, either alive or dead, were included. Birth weights were corrected to female singles to remove sex and twinning effects before analyses were made.

The preliminary analysis of birth weights shown in table 3 indicates that the differences among the subclass treatment means were greater than could be attributed to random variation. However, none of the main effects are significant but certain interactions involving treatments *a* and *d* were more divergent than expected by chance alone. For example, the interaction AD is significant. It means that the response to feeding supplement in *d* to ewes not supplemented in *a* differs from that of feeding supplement in *d* to ewes that were supplemented in *a*.

There is no obvious biological interpretation. The over-all picture appears to be that feeding concentrates in amounts used in this experiment has little influence on the birth weights of lambs.

Weaning Weight. The 437 lambs alive at weaning time represent the progeny of 362 ewes. The preliminary analysis of the weaning weights (table 3) indicates that there was no significant influence of the 32 sub-class treatments. The data were re-analyzed after correcting for age of lambs at weaning but no significant treatment effects were observed. In addition, a covariance analysis of birth weights and weaning weights showed that gains from birth to weaning was not related to the treatments applied to the ewes. Thus, from the standpoint of weaning weights, it is difficult to justify the feeding of concentrate to ewes when conditions are similar to those encountered in this experiment.

Number of Lambs Born (Fertility of Ewe). Feeding concentrates in *a* and *b* increased the fertility of the ewes in this experiment. Differences of 10 and 9 more lambs born per 100 ewes due to feeding concentrates in *a* and *b*, respectively, are noted in table 5. This is in contrast to *c* and *d* where differences of only 1 and 4 lambs per 100 ewes respectively, are noted. Ewes in good condition averaged 11 more lambs per 100 ewes than thin ewes.

The differential response of thin ewes and good condition ewes to feeding concentrates is shown in table 6. The difference of 15.8 between feeding and not feeding concentrates in *a* to thin ewes is the only one that is significant as indicated by the *t* test. A high experimental error is noted for these data and also for the data on lambs born dead and lambs weaned. The analyses of variance shown in table 7 indicates that condition and period *a* are the most important factors affecting the variance of lambs born but even these mean squares are not quite large enough to show statistical significance in view of the large sampling error. There is reason to suspect the sampling

TABLE 5. EFFECTS OF FIVE MAIN TREATMENTS ON THE LAMB CROP

Treatment	No. of ewes	Birth weight	Weaning weight	Number of lambs per 100 ewes			
				Born	Born dead	Dead or missing to weaning	Weaned
		(Lbs.)	(Lbs.)				
a. Pre-breeding							
Fed	236	11.1	80.5	130	13	20	97
Not Fed	224	10.9	79.0	120	10	16	94
Difference		+ .2	+ 1.5	+ 10	+ 3	+ 4	+ 3
b. Breeding							
Fed	227	10.9	80.0	130	15	20	95
Not Fed	233	11.1	79.6	121	9	17	95
Difference		− .2	+ .4	+ 9	+ 6	+ 3	0
c. Early Pregnancy							
Fed	229	11.0	79.8	126	12	17	97
Not Fed	231	11.0	79.7	121	12	20	93
Difference		.0	+ .1	+ 5	0	− 3	+ 4
d. Late Pregnancy							
Fed	237	11.1	80.5	127	10	18	99
Not Fed	223	10.9	79.0	123	13	20	90
Difference		+ .2	+ 1.5	+ 4	− 3	− 2	+ 9
e. Ewe condition							
Good	202	11.1	80.7	131	10	20	101
Poor	258	10.9	79.0	120	12	18	90
Difference		+ .2	+ 1.7	+ 11	− 2	+ 2	+11

error to be an over-estimate since it is calculated only among the 32 different subclasses. A separate chi square analysis showed that the difference due to condition was significant while none of the feeding treatments were significant.

Number of Lambs Born Dead. Tables 5 and 6 show that a larger number of lambs were born dead in the groups fed concentrates in *a* and *b* where higher fertility was observed. This could result from the fact that more twin lambs were produced in these groups and that these tend to be smaller and weaker than single lambs. However, no statistical significance could be attached to any of the primary treatments nor any of the first order interactions of the feeding treatments with condition. This is shown by the analysis of variance in table 7. Under the conditions of this experiment, therefore, there is no evidence that feeding or condition has any important effect on mortality of lambs at birth.

Survival of Lambs to Weaning. Mortality of lambs from birth to weaning is lower for those ewes given supplement in *c* and *d* but the differences found in tables 5 and 6 are not large enough for statistical significance. On the other hand, a larger number of lambs were weaned from those ewes fed supplement in *c* and *d* as observed in table 5. Feeding supplement in *d* produced 9 more lambs weaned per 100 ewes than did not feeding supplement

TABLE 6. THE EFFECT OF FEEDING SUPPLEMENT TO POOR AND GOOD CONDITION EWES ON THE SIZE OF THE LAMB CROP

Period	Treatment	Number of lambs per 100 ewes:							
		Born		Born dead		Dead or missing to weaning		Weaned	
				Condition of ewes					
		Poor	Good	Poor	Good	Poor	Good	Poor	Good
a	Fed	128.4	132.4	11.9	13.4	23.2	16.6	93.3	102.4
	Not Fed	112.6	129.6	11.5	7.4	12.3	23.1	88.8	99.1
	Difference	+15.8	+2.8	+ .4	+6.0	+10.9	−6.5	+ 4.5	+ 3.3
b	Fed	125.9	132.6	13.0	14.0	18.3	23.0	94.6	95.6
	Not Fed	115.1	129.4	10.4	6.8	17.7	16.8	87.0	105.8
	Difference	+10.8	+3.2	+2.6	+7.2	+ .6	+6.2	+ 7.6	−10.2
c	Fed	123.9	126.6	11.4	11.2	17.0	15.8	95.5	99.6
	Not Fed	117.1	134.4	12.0	9.5	18.6	24.0	86.5	101.9
	Difference	+ 6.8	−8.8	− .6	+1.7	− 1.6	−8.2	+ 9.0	− 2.3
d	Fed	122.6	133.4	10.6	9.2	16.0	21.2	96.0	103.0
	Not Fed	118.4	128.6	13.8	11.5	19.6	18.6	86.0	98.5
	Difference	+ 4.2	+4.8	−2.2	−2.3	+ 3.6	+2.6	+10.0	+ 4.5

in this period. However, this difference is not significant. The good-condition ewes weaned 11 more lambs per 100 ewes than those in poor condition, which is due mainly to higher fertility.

Discussion

Fertility of the flock appeared to be increased by feeding in periods *a* and *b*. This is in agreement with general practice. Feeding in *c* and *d* tended to reduce the number of lambs dying up to weaning thereby increasing the number of lambs surviving at weaning time. Ewe condition appeared to be the most important factor determining the number of lambs born and weaned. However, the results from this experiment alone are not conclusive.

Birth and weaning weights of the lambs show little or no response to the feeding treatments. Ewe gains show a direct increase due to feeding with each successive feeding treatment. Fleece weights were increased by feeding in period *c*. These findings indicate that even when thin ewes are maintained

throughout the period of pregnancy on mixed hay from one-third to one-half legume, feeding a concentrate supplement is of questionable economic value.

Although the correlation between ewe gains and lamb weaning weights was not computed in this experiment, a comparison of the results of the detailed analyses would suggest that no such correlation exists. Arnett, *et al.* (1926), reporting on an experiment with beef cows at the Montana Station, concluded that winter gains of the cows was not correlated with weight of the calves at weaning time. Vinke and Dickson (1933) also working with beef cows, confirmed the earlier work of Arnett; they reported that

TABLE 7. ANALYSIS OF VARIANCE OF SIZE OF LAMB CROP (MEAN SQUARES ONLY)

Treatment	d/f	No. lambs born	No. lambs born dead	No. lambs dead or missing to weaning	No. lambs weaned
E	1	882	14	34	761
A	1	684	81	38	121
B	1	392	195	94	16
C	1	8	2	195	92
D	1	162	38	2	421
AE	1	338	63	672	2
BE	1	112	42	52	594
CE	1	480	12	88	252
DE	1	0	0	75	60
Remainder	22	221	75	216	233

winter gains were not associated with birth weight of the calves. They found that cows wintered on straw alone were so weak in the spring that they had to be "tailed up" at calving time, but the calves were of normal weight when weaned. They concluded that for cows winter rations and winter gains are important only as a means of providing the proper amount of feed to maintain the weight of the cows from year to year. This same conclusion might be applied to the ewes in this experiment.

Baxter (1944) observed in England that cows receiving no concentrates (hay only) prior to calving produced less milk in the early stages of lactation than those cows which did receive concentrates prior to calving. It may have been entirely possible in this experiment that those ewes receiving the concentrates during certain "critical" periods also produced more milk. However, the differences must not have been very great or persisted for any length of time, since no detectable differences were noted in the weaning weight of the lambs.

The value of a supplement feed would be determined from the effect it

produces in relation to the cost of the feed. At 2¢ a pound for beet pulp pellets it would cost $14.00 per 100 ewes to feed supplement for the pre-breeding period in this experiment, $26.00 for the breeding period, $90.00 for the early pregnancy period, and $22.00 for the late pregnancy period. If lambs sell at $20.00 per cwt., then the production of just one additional lamb per 100 ewes would pay for the supplement fed during pre-breeding. Producing two additional lambs would pay for the feed during the breeding season, while five or six additional lambs would pay for the feed during the early pregnancy period and one to two lambs would pay for the feed during the late pregnancy period. From nine to eleven more lambs per 100 ewes would need to be produced to pay the cost of the supplement for the entire four periods.

The type of experimental design used in this investigation would be useful to make additional studies on the influence of prenatal factors of nutrition and management on postnatal performance. Range cattle and sheep are especially well adapted to this type of experiment. In the present case in spite of the complexity of the experiment only two groups of animals were handled at any one time. Even then the band was divided for only a short time each day while one group was put on feed. Where small treatment differences are encountered this design can provide a precise and efficient estimate of such differences. It should be noted that sixteen different feeding treatments were imposed upon a flock of 462 ewes with little labor or equipment expenditure.

Summary

The results of supplementing range breeding ewes with beet pulp pellets during the pre-breeding, breeding, early pregnancy, and late pregnancy periods are presented. The effects of feeding are evaluated in terms of body-weight gains, fleece weight, date of lambing, and fertility of the ewes, and for the lambs in terms of birth weight, weaning weight and survival to weaning time. There were 462 ewes started on the experiment.

The treatments were arranged in a 2^5 factorial design with supplement versus no supplement in four periods and good versus poor condition providing the basic treatments. This arrangement permitted the flock to be handled as a unit except at feeding time.

Ewe gains reflected the influence of feeding in the breeding and early pregnancy periods. In the pre-breeding and breeding periods the thin ewes showed greater response to feeding supplement than the good condition ewes. During the early pregnancy period the good condition ewes gained the most. Also feeding supplement in this period produced .37 pound more fleece.

No important effects on birth or weaning weights were observed from the feeding treatments.

Flock fertility was increased by 10 and 9 percent by feeding supplement in the pre-breeding, and breeding periods, respectively. Good condition ewes produced 11 percent more lambs at birth and at weaning than the thin ewes.

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EFFECT OF VITAMIN A SUPPLEMENTATION ON REPRODUCTION OF EWES GRAZED ON GREEN AND DRY SUMMER RANGES[1,2]

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Hart and Guilbert (1933) found a high percent of abortions and still births in both cattle and sheep that had been carried on dry range. They reported that the animals showed symptoms of night blindness, capricious appetites, intermittent diarrhea, general unthrifty condition, and pulmonary complications. Pearson *et al.* (1945) stated that night blindness in sheep is one of the first symptoms of a vitamin A deficiency. This is usually followed by nervous disorders causing various degrees of incoordination. They also found that urinary calculi might occur as one of the late symptoms and may be the immediate cause of death. Similar findings are reported by Schmidt (1944).

Miller *et al.* (1942) found that with old ewes, 22 to 23 months were required to develop night blindness on a low carotene ration, whereas ewe lambs that had access to green grass as nursing lambs, required only 9 months. Gunn *et al.* (1942), and Lindley *et al.* (1948), in work with rams, produced vitamin A deficiency symptoms within two to four and one-half months after feeding a vitamin A deficient ration.

Hart and Miller (1937) reported that a low vitamin A intake in adult ewes over a period of 5 months, including the breeding season, did not affect the number of lambs born as compared to control animals supplied with vitamin A. When ewes were depleted to the point of night blindness at breeding time, gestation was unsuccessful.

Shrewsbury *et al.* (1942) found that a ration of oat straw was deficient in protein and probably also in vitamin A, as based on milk production of ewes and growth of lambs.

Experiment I

A great deal of poor-quality, bleached hay is fed to sheep in the western range areas. In an effort to duplicate some of the rancher's conditions, certain poor-quality roughages were used to determine their adequacy as a source of carotene for reproduction and lactation of ewes. The four roughages

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studied were alfalfa hay (*Medicago sativa*), wheat hay (*Triticum vulgare*), smooth bromegrass straw (*Bromus inermis*), and big bluegrass straw (*Poa ampla*).

Materials and Methods

Four lots of seven-year-old grade Rambouillet ewes were fed the dry-lot rations indicated in table 1. Before being placed on experiment the ewes were

TABLE 1. ROUGHAGES FED AND FEED CONSUMPTION

Lot No.	No. ewes	Roughage fed	Average daily consumption per ewe throughout the experiment				
			Hays lbs.	Concentrates, lbs.	Total protein, lbs.	T.D.N., lbs.	Carotene in feed,[4] Mg.
1 and 1a	12[1]	Alfalfa	3.27	0.69[2]	0.50	2.16	9.63
2 and 2a	12[1]	Wheat Hay	3.07	0.96[2]	0.48	2.17	1.29
3 and 3a	10[1]	Smooth Bromegrass Straw	1.73	1.65[3]	0.46	2.03	4.54
4 and 4a	10[1]	Big Bluegrass Straw	1.84	1.55[3]	0.46	2.00	7.63

[1] Half of the ewes in each lot received 100,000 I.U. of vitamin A weekly. Ewes with and without vitamin A were fed and kept together in the same lot.

[2] Ewes in lots 1 and 2 received a concentrate mixture of ground oats 20, barley 35, wheat bran 20, and soybean oil meal 25.

[3] Ewes in lots 3 and 4 received a concentrate mixture of ground oats 20, barley 20, wheat bran 25, and soybean oil meal 35. A higher protein mixture was fed in these two lots in order to compensate for the lower protein content of the two grass straws fed.

[4] The carotene content of the roughages and concentrate mixtures was as follows in micrograms per gram: alfalfa, 6.4; wheat hay, 0.8; smooth bromegrass straw, 5.4; big bluegrass straw, 8.8; and both concentrate mixtures 0.4.

grazed on green mountain feed consisting of pea-vines, pinegrass, and browse such as willow, maple, and buck brush. For the two-weeks period just before breeding, however, the ewes were fed entirely on green sweet corn refuse silage. The animals were divided into the four groups shown in table 1. Half of the ewes in each lot were given 100,000 I.U. of vitamin A[5] weekly by means of capsules. Ewes, fed each different roughage, with and without vitamin A, were kept in the same lot and the different lots were housed in separate sheds which had small outside runs.

The ewes had access to all of the roughage they could eat. Wasted or refused roughage was weighed back at frequent intervals. The amount of grain fed was regulated so that the ewes were all obtaining approximately the same amount of protein and total digestible nutrients. Salt and steamed bone meal were fed *ad libitum*.

[5] Bio-Vita 10Ma, Natural shark liver oil blend containing 10,000 I.U. of vitamin A per gram. Kindly supplied by R. T. Carruthers of Bioproducts, Inc., Astoria, Oregon.

The alfalfa used was of medium quality. The wheat hay was cut at the soft dough stage. The grass straws were salvage material from seed production. Both of the grass straws were harvested at the hard dough stage. None of the roughages used had been rained upon.

The ewes were weighed at two-week intervals throughout the experimental period. The lambs were weighed at birth and at weekly intervals thereafter.

Results and Discussion

The data in table 1 show the feed consumption records of the ewes.

In this experiment it was found that the alfalfa and wheat-hays were very palatable to the ewes. On the other hand, the grass straws were unpalatable. Because the ewes ate only about half as much of the two grass straws as they did of the more palatable wheat hay and alfalfa hay, it was necessary to feed a larger amount of grain and protein supplement to the animals receiving the grass straws in order to equalize the intake of protein and total digestible nutrients. The amount of concentrate mixture fed was regulated so that at the end of the experimental period, all the animals had consumed approximately the same amount of total protein and the same amount of total digestible nutrients.

The carotene intake in the feed was somewhat different for the different lots of ewes (table 1). The highest intake was obtained by those fed alfalfa hay, whereas the ewes fed wheat hay had the lowest intake of carotene.

Table 2 shows the data obtained on the gains during pregnancy and the loss in weight during lactation. On the average, ewes of all lots gained very well during pregnancy and there were no significant differences in the weight loss by the ewes on the different rations during lactation.

Three ewes died of pregnancy disease during the experiment. Foss and Eveleth (1944) reported that a vitamin A deficiency may be a predisposing factor in the production of ketosis in pregnant ewes. In this experiment, however, it was the opinion of the investigators that the pregnancy disease was due to other causes inasmuch as two of the three affected ewes had been receiving the vitamin A supplement for approximately five months prior to lambing. The vitamin A blood level of the ewes that died of pregnancy disease was still quite like that of the other ewes in their respective lots.

Each week throughout the trial the blood of all the ewes was assayed for its vitamin A content by the method of Kimble (1939). These data are shown in table 2. Regardless of the difference in vitamin A supplement or carotene content of the ration, no significant differences were found in the blood levels of vitamin A in the different groups of ewes. This indicates that possibly there is a physiological limit on the vitamin A content of the blood

since the blood levels of the ewes receiving 100,000 I.U. of vitamin A per week were not significantly higher than the blood levels of unsupplemented ewes. This same finding was obtained in experiment II.

The data on the vitamin C levels of the blood indicate that the addition of vitamin A to the various rations did not result in any significant increase in vitamin C synthesis. This might be expected since vitamin A blood levels were in the normal range in all lots of ewes.

TABLE 2. WEIGHT AND BLOOD RECORDS OF EWES DURING GESTATION AND LACTATION

Lot No.	No. ewes	No. ewes lambing	Average Initial weight of ewes lambing, lbs.	Average gain to parturition lbs.	Lactation record			Blood plasma vitamin A, micrograms per ml.***	Blood plasma vitamin C, mg. per cent***
					No. ewes lactating	Average days of lactation	Average weight loss of ewes during lactation,** lbs.		
1	6	6	142.3	43.5	4	49.2	46.7	0.21	0.77
1a*	6	6	130.5	45.6	5	45.1	50.0	0.24	0.80
2	6	4[1]	143.0	40.5	5	47.2	46.5	0.21	0.59
2a*	6	5[2]	136.8	40.5	3	46.0	43.7	0.26	0.78
3	5	4[3]	137.7	39.0	2	52.5	47.0	0.23	0.82
3a*	5	2[4]	128.0	26.5	1	46.0	42.6	0.20	0.67
4	5	5	139.8	41.8	4	43.7	48.2	0.21	0.82
4a*	5	3[5]	143.5	42.5	2	46.3	45.3	0.23	0.71

* Ewes in these lots received vitamin A.

** Includes weight of fetus, fluids, membranes, etc. at lambing.

*** Ewes were bled every week. Average value for all analyses before lambing.

[1] One ewe barren, one ewe died of pregnancy disease.

[2] One ewe died of casecus lymphadenitis.

[3] One ewe was barren.

[4] One ewe was barren, one died of internal hemorrhages, and one died of pregnancy disease.

[5] Two barren ewes, one died of pregnancy disease.

Table 3 gives the data on the lambing records and growth of the lambs during the early suckling period. The ewes of all lots produced strong, healthy lambs. Although the numbers are small and there was considerable variation from lamb to lamb, no differences large enough to be statistically significant were found between the birth weights or growth rates of the lambs from ewes in the various lots.

Experiment II

Large numbers of western range sheep are grazed on poor-quality dry ranges each year and then, as stated before, frequently wintered on poor-quality hay. In this experiment a comparison was made between good, green

TABLE 3. LAMBING RECORD

				Birth weights										Lamb growth rates			
				All lambs			Singles		Twins		Triplets			Lambs raised as singles		Lambs raised as twins	
Lot	No. ewes lambing	No. lambs born	No. lambs dying	No.	Average vigor score**	Average weight, lbs.	No.	Average weight, lbs.	No.	Average weight, lbs.	No.	Average weight, lbs.		No.	Average daily gain, lbs.	No.	Average daily gain, lbs.
1	6	9	4	9	1.1	10.1	3	10.7	6	9.4				3	0.55		
1a*	6	10	2	10	1.6	10.5	3	12.8	4	10.0	3	8.8		3	0.56	4	0.43
2	4	5	0	5	1.0	12.5	3	13.8	2	10.4				3	0.53	2	0.29
2a*	5	7	1	7	1.0	12.8	3	13.2	4	12.5				3	0.54		
3	4	7	2	7	1.3	11.5	1	14.0	6	11.1				1	0.53	2	0.29
3a*	2	3	0	3	1.0	9.9	1	13.5	2	8.1				1	0.50		
4	5	6	0	6	1.0	12.2	4	14.1	2	8.8				3	0.47	2	0.16
4a*	2	2	0	2	1.0	13.0	2	13.0						2	0.51		

* Ewes in these lots received vitamin A.

** Excellent—1; Good—2; Medium—3; Fair—4; Poor—5; Dead—6.

range and poor, dry range[6] as a source of carotene and for their subsequent effects on reproduction and lactation in ewes which were afterward wintered on poor-quality hay.

Materials and Methods

Two groups of 25 three-year-old grade Rambouillet range ewes were used in this experiment. One group of these ewes, with lambs at their side, was placed on good green sweet clover and grass range, beginning in early summer, for a period of three and one-half months. For the same period of time, the other group of ewes, with their lambs, was placed on poor-quality, dry crested wheatgrass range. In the latter case there was an adequate amount of forage available, but it was dry and bleached. These ewes were all brought together in early fall and their lambs weaned. The ewes were then placed in dry-lot and were all fed the same ration consisting of poor-quality hay[7] plus a concentrate mixture supplement[8] for the next ten months. Beginning immediately after all the ewes were bred, half of the ewes in each group were given 100,000 I.U. of vitamin A weekly by means of capsules. The ewes were fed liberal amounts of hay and grain so that their requirements for protein and total digestible nutrients would be met. Salt and steamed bone meal were fed *ad libitum*.

Results and Discussion

The data in table 4 show the feed, weight, and blood records of the ewes and the carotene content of their ranges and their feeds. The feeds were analyzed for carotene after obtaining a representative sample during the course of the winter feeding period. The ranges were sampled each month during the grazing season by taking clippings from different areas of the range and pooling these samples.

The ewes that were grazed on the green range for a three and one-half months period gained an average of 7 pounds per head. Their 27 lambs gained a total of 1,652 pounds or an average gain of 61.2 pounds per lamb. The ewes that were on the dry range lost an average of 13 pounds per head for this same grazing period. Their 27 lambs gained a total of 686 pounds or an average gain of 25.4 pounds per lamb. These significant differences indicate that the dry range was lacking in nutrients as measured by the loss in weight of the ewes and the small amount of growth of the lambs.

[6] The cooperation of Mr. John M. McGregor, Hooper, Washington, in furnishing the dry range gratis is gratefully acknowledged.

[7] Poor-quality hay consisting of smooth brome grass hay containing 4.6 micrograms per gram of carotene and oat and barley hay containing 7.8 micrograms per gram of carotene.

[8] Concentrate mixture consisting of oats 50, barley 25, wheat bran 10, soybean oil meal 10, and dried molasses beet pulp 5 parts by weight and containing 0.3 micrograms per gram of carotene.

TABLE 4. FEED, WEIGHT, AND BLOOD RECORDS OF EWES DURING RANGE FEEDING, GESTATION, AND LACTATION

Group No.	Lot No.	No. ewes	Type of summer range on previously	Average weight ewes when bred,[3] lbs.	No. ewes lambing	Average gain to parturition, lbs.	Average weight loss at lambing, lbs.	Average weight change during lactation, lbs.	Blood plasma vitamin A micrograms/ml.	
									Ewes when brought from range	After lactation
1	1	9	Green[1]	157.5±5.24	4[4]	14.5±4.75**	26.0±2.42	8.5±4.93	0.526±0.03	0.397±0.03
	1a***	8	Green[1]	157.5±4.47	6[5]	46.0±2.79	31.5±3.04	−10.0±4.53	0.468±0.02	0.427±0.02*
2	2	7	Dry[2]	144.1±3.41	6[6]	46.5±3.52**	21.8±2.62	− 5.0±4.61	0.433±0.02	0.313±0.02*
	2a***	8	Dry[2]	138.3±5.25	7[7]	44.3±3.63	30.3±2.95	1.0±4.70	0.445±0.03	0.393±0.20—

* Significant at 5% level.
** Significant at 1% level.
*** Ewes in these lots received vitamin A.
[1] The green range contained 210 micrograms per gram of carotene on a dry weight basis.
[2] The dry range contained 2.9 micrograms per gram of carotene on a dry weight basis.
[3] The ewes were fed 3 lbs. of hay and 2 lbs. of concentrates per ewe daily (each day's ration containing 8.4 mgs. carotene).
[4] Two ewes barren, one ewe died of pulmonary hyperemia and edema, one ewe aborted lambs and died, and one ewe died of necrotic metritis, vaginitis and cervicitis after lambing.
[5] One ewe barren, and one ewe died of ketosis and pulmonary and renal abscesses.
[6] One ewe barren.
[7] One ewe barren.

The ewes were placed in the feed lot in early fall and bred during early winter. All the ewes were kept together during the time they were on experiment in dry-lot. Of the original fifty ewes, only thirty-two were used in this trial.

Table 4 shows the data obtained with the ewes during pregnancy and lactation. There were no significant differences in the weights of the ewes in the four lots at the time they were bred.

During gestation, however, the ewes in lot 1a (green range plus vitamin A) made highly significantly greater gains than the ewes in lot 1 (green range—no vitamin A). The ewes in lot 2 (dry range—no vitamin A) also made highly significantly greater gains than did the ewes in lot 1. Some of the ewes that had been on dry range were thin, and it would be expected that they would gain more weight during pregnancy than heavier ewes. The lots of ewes (2 and 2a) that had been on dry range made very nearly the same gains during pregnancy. No significant difference was indicated here. Neither was there any significant difference between the gains made by the ewes in lot 1a and those in lot 2a (dry range plus vitamin A).

Table 4 indicates that the mean differences between the weight losses at lambing time of the 4 lots of ewes were considerable. Due to the large variation within groups, however, these differences are statistically not significant. Similarly there were even greater differences existing in the weight change of the ewes in the 4 lots after lactation. Due again to the large variation within lots and the small numbers of animals, these differences are not significant.

The ewes which were taken off the green and the dry range and placed in dry-lot had high levels of vitamin A in their blood and there was no significant difference in the blood levels of the vitamin in the two groups. Half of the ewes in each of these two groups (lot 1a from green range and lot 2a from dry range) were given added vitamin A during gestation and lactation. There was no significant difference in the blood levels of vitamin A after the lactation period of the ewes which had been on the green range (lots 1 and 1a) during the summer months, with or without vitamin A during gestation and lactation. This is evidence of the great storage of vitamin A by the ewes on the green range.

The ewes that had been on dry range during the summer (lot 2) had a significantly lower level of vitamin A in their blood after the lactation period than the ewes (lot 2a) that had received vitamin A during gestation and lactation. The ewes in lot 1 (green range—no vitamin A) also had a significantly higher level of vitamin A in the blood after lactation than the ewes in lot 2 (dry range—no vitamin A). There was no significant difference in the blood levels of vitamin A of the two lots of ewes (1a and 2a) that had received the vitamin A supplement.

Even though the blood levels of vitamin A were lower in the ewes that had been on dry range, the vitamin A blood levels were still in the normal range (the normal range is 0.15 to 0.48 microgram per ml. of blood as reported by Paulsen *et al.*, 1944). Thus it would seem that the ewes that had been on the dry range probably made efficient use of the small amounts of carotene present and must have been able to store vitamin A over long periods of time. This is similar in nature to the findings of Miller *et al.* (1942), who found that, with aged ewes, 22 to 23 months were required to produce night blindness symptoms.

The lambing record of the ewes is given in table 5. The percent lamb crop born and the percent lamb crop reared appears greater in both lots of ewes which had received vitamin A supplement (lots 1a and 2a). However, the only significant difference occurred between lots 2 and 2a. The ewes in lot 2a (dry range plus vitamin A) gave birth to a significantly greater number of lambs than the ewes in lot 2 (dry range—no vitamin A). There was only a small number of ewes involved, however.

TABLE 5. LAMBING RECORD

Lot	No ewes lambing	Per cent lamb crop born	Per cent lamb crop weaned	Birth weight all lambs, lbs.	Average daily gain to end of expt.,[6] lbs.	Blood plasma vitamin A, micrograms/ml.
1	4[1]	175	125[2]	10.0 ±0.55	0.500±0.03	0.15±0.01
1a***	6	200	150[3]	10.9 ±0.47	0.355±0.03*	0.19±0.02
2	6	117	100[4]	11.25±0.70	0.546±0.04	0.17±0.02
2a***	7	200	143[5]	9.05±0.44	0.436±0.02*	0.21±0.01

* Significant at 5% level.
*** Ewes in these lots received vitamin A.
[1] One ewe died soon after lambing.
[2] Two lambs were still-born.
[3] Three lambs died soon after birth.
[4] One lamb died soon after birtn.
[5] Two lambs were still-born, two died soon after birth.
[6] These lambs were carried on experiment for approximately two months.

Comparing the birth weights of the lambs, the lambs in lot 1a had a significantly greater birth weight than the lambs in lot 2a. Comparisons between other lots did not show any significant difference in birth weights.

The average daily gain was used in comparing the growth rates of the lambs instead of using their final weight. This was done because there was considerable difference in the ages of the lambs and it makes for more uniform measurement of growth. The lambs in lot 1 made a significantly greater average daily gain than the lambs in lot 1a. This is different from what might be expected; but with the small numbers in the experiment, even

though the difference is statistically "significant," the element of chance must not be overlooked. The lambs in lot 2a (dry range with vitamin A) made a significantly greater average daily gain than the lambs in lot 1a. This is no doubt due to the fact that in the lot of lambs from ewes on dry range plus vitamin A, the lambs were raised mostly as singles, while in the lot of lambs from ewes on green range plus vitamin A, the lambs were raised mostly as twins. No other significant differences were found between the various lots of lambs in their average daily gain.

Observations of the means of the blood vitamin A levels of the 4 lots of lambs would seem to indicate a trend in favor of vitamin A supplementation. These differences were shown to be statistically not significant.

Throughout this experiment the only benefit that seemed to be derived from vitamin A supplementation was a small increase in the blood levels of vitamin A in some of the ewes. This improvement in the blood levels was not expressed, to any consistently significant extent, in percentage lamb crop, birth weights, vigor, or growth rates of the lambs. While certain significant differences were shown, they were not consistently in favor of, or against, vitamin A supplementation. Since the ewe is able to store vitamin A over long periods of time, it is probable that total protein and total digestible nutrients are the limiting factors when ewes have access to green range and are fed poor quality hays during gestation and lactation. Under the conditions of the experiments reported herein, covering a period of two years, when the poor quality hay is supplemented with additional protein and total digestible nutrients, the performance of the ewes fed under these conditions is essentially equal to that of those fed good quality hay or those that had received a vitamin A supplement.

Summary

Ewes grazed on green mountain feed and then fed poor-quality, low carotene roughages with a grain supplement to supply extra protein and total digestible nutrients during the winter were not benefited by vitamin A supplementation.

When range ewes were grazed on either green or dry summer range and then fed poor-quality hay during gestation and lactation, the only benefit that seemed to be derived from vitamin A supplementation of the poor-quality hay was a small increase in blood levels of vitamin A in some of the ewes. This improvement in blood levels was not expressed, to any consistently significant extent, in percentage lamb crop, birth weights, vigor, or growth rates of the lambs.

The good results obtained with all poor-quality roughages studied was probably influenced by the fact that additional concentrates were fed so

that total protein and total digestible nutrient intakes were not limiting factors and were about the same in all lots. Under the conditions of this experiment, the further supplementation of these poor quality roughages with vitamin A did not seem to be of any help.

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NEWS AND NOTES

It is expected that Fulbright programs of international education exchange will be initiated in the near future with Australia, Egypt, Iran, Turkey and India, since an agreement has been signed recently with each of these countries. Any person wishing to apply for an award as advanced research scholar or visiting lecturer in any one of these countries is encouraged to write the Executive Secretary of The Committee on International Exchange of Persons, Conference Board of Associated Research Councils, 2101 Constitution Avenue, Washington 25, D. C. Application forms for the United Kingdom and British Colonial Dependencies, Belgium and Luxembourg, France, Greece, Italy, The Netherlands, Burma, The Philippines, New Zealand and Norway, for the academic year 1951–52, will be sent to interested individuals in the late summer or early autumn when the programs for that year are available.

The forty-second annual meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago, Illinois on November 24 and 25, 1950 with a dinner for the honored guest on November 26.

Jorge de Alba, formerly of Cornell University, has taken the position of Physiologist, at the Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica. He had previously spent five years organizing a large hereford breeding estate in Coahuila, Mexico.

W. N. McMillen received his Ph.D. degree in Animal Husbandry and the Institute of Nutrition at Michigan State College in June. He is now Associate Director of Research, Allied Mills, Inc., Libertyville, Illinois.

K. F. Warner, extension meat specialist, USDA, and E. F. Rinehart, extension animal husbandman, University of Idaho, were among the persons receiving "Superior Service" awards at the hands of the Secretary of Agriculture in Washington, May 25, 1950.

George A. Brown and Ralph S. Hudson were signally honored on the Michigan State College campus on May 4, in ceremonies marking their retirement from active duty in the Institution after 42 years' service. Included in the program was the presentation of their portraits to the Institution.

R. H. Nelson succeeded George A. Brown as head of the Michigan State College Animal Husbandry Department when the latter recently retired.

Claude Harper, head of Purdue's Animal Husbandry Department, and Mrs. Harper are spending about two months in Europe this summer, both on the Continent and in Britain.

Howard J. Brant, who has been secretary of the Belgian Draft Horse Association for several years, became secretary of the American Berkshire Association on July 1, 1950.

J. L. Krider, head of the swine division, Animal Science Department, University of Illinois, resigned effective July 1, to accept a position in private industry.

Charles I. Bray, veteran animal husbandman, and lately in charge of research in livestock production at the Louisiana State University, died in April.

L. K. Bear, extension animal husbandman, Ohio State University, resigned in April to accept a position with the Ohio Producers Livestock Cooperative Association with headquarters in Columbus.

Thomas E. Wiley, B.S., Ohio State and M.S. from Wisconsin, was appointed 4-H livestock specialist in the New York Extension Service, February 1, 1950.

Doyle Chambers, a native of Arkansas, who received his B.S. and M.S. degrees at Louisiana State and Ph.D. at Oklahoma A. & M. College, was recently made associate professor of animal husbandry at the latter institution, in animal breeding work.

W. L. Blizzard, of Oklahoma A. & M. College was recently honored by having the 1950 Oklahoma City Junior Livestock Show dedicated to him. A portrait of the Dean was presented to the Oklahoma City livestock market, where it will occupy a prominent place in the exchange building.

John Goe, of Colorado and with previous experience in USDA was made chief of the wool division, P. & M. A. to fill the vacancy created by the death of Frank Cronin.

Peter McKenzie, who had charge of livestock at Pennsylvania State College for 35 years, retired from that position on June 1, to become livestock manager of the large farming operation at Camp Hill, Pennsylvania.

H. H. Levick and E. E. Grissom of Mississippi State College, and F. I. Dahlberg of Texas A. & M. College, were guests on a recent educational tour conducted by Swift & Company.

Charles G. Hunt, with degrees in animal husbandry from Oklahoma A. & M. College and Ohio State College, and an Army veteran, recently joined the field service staff of the American Hereford Association, with headquarters at Kansas City, Missouri.

Howard G. Lewis, formerly on the animal Husbandry staff at North Dakota State College and at Montana State College, has become manager of a hereford ranch at Bozeman, Montana.